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Characterization of the Homogeneous Reactor Experiment No. 2 (HRE) Impoundment

R. G. Stansfield
C. W. Francis

Environmental Sciences Division
Publication No. 2687

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ENVIRONMENTAL SCIENCES DIVISION

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ABSTRACT

STANSFIELD, R. G., and C. W. FRANCIS. 1986. Characterization of the Homogeneous Reactor Experiment No. 2 (HRE) Impoundment. ORNL/TM-10002. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 118 pp.

A characterization study was conducted on a radioactive waste impoundment for the Homogeneous Reactor Experiment No.2 (HRE) at the Oak Ridge National Laboratory, to provide information necessary for its proper disposition. The impoundment received low-level radioactive wastes from 1957 until 1963. In 1970, the pond was backfilled with clay soil and the impoundment capped with asphaltic concrete, but no wastes were removed.

The mixed soil fill and sediment, approximately 4.8 m (16 ft) deep, was sampled using soil boring methods. The samples were analyzed to determine if the material would classify as a hazardous waste under regulatory definitions promulgated in accordance with the Resource Conservation and Recovery Act (RCRA). The impoundment is not regulated under RCRA because it was a land disposal unit and received no wastes after November 19, 1980. However, if the soil and sediment mixture contained RCRA-defined hazardous waste, it would be subject to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Chemical analyses indicate that the sampled material does not contain hazardous chemical constituents above the levels permitted by RCRA regulations. The sediment was found to contain an estimated radioactivity inventory of approximately 2700 GBq (70 Ci) of ^{90}Sr and 600 GBq (16 Ci) of ^{137}Cs.

The impoundment was excavated in clay soil and weathered sedimentary rock of the Conasauga Group. Four wells for monitoring the groundwater were constructed around the perimeter of the impoundment to depths ranging from 7.6 to 9.1 m (25 to 30 ft). Sampling and analyses of the groundwater have been completed for the winter and spring seasons (1985) and will be continued in the future for at least two more quarters, to account for possible natural seasonal variation in groundwater quality. At that time, the effect of the impoundment on the groundwater quality will be determined. Analyses from the first-two quarters indicate that radioactivity (gross beta resulting from predominately ^{90}Sr) of the groundwater exceeds limits allowed by RCRA regulations.

1. INTRODUCTION

This characterization study of the Homogeneous Reactor Experiment No. 2 (HRE) impoundment at Oak Ridge National Laboratory (ORNL) has been conducted under the Surplus Facilities Management Program (SFMP) to provide information necessary for proper disposition of the facility. The SFMP at ORNL is part of the Department of Energy's (DOE) National SFMP, administered by the Richland Operations Office. This program provides for the management of radioactively contaminated DOE facilities from the end of their operating life until final disposition is completed. The work has been performed with a view towards obtaining the information in such a format that it would also be useful in assisting ORNL in fulfilling any obligation that may develop under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

1.1 COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION AND LIABILITY ACT

Disposal impoundments that contain hazardous wastes but that stopped receiving such wastes prior to November 19, 1980, are regulated under CERCLA rather than the Resource Conservation and Recovery Act (RCRA). The subject impoundment last received water from HRE in 1960 and has been listed as a possible hazardous waste facility with the Environmental Protection Agency (EPA) and the Tennessee Division of Solid Waste Management (TDSWM). Under CERCLA regulations, the original listing of the site did not require sampling and analysis of the waste, but was allowed to be based on "the respondent's belief, recollection and examination of available records" (FR Vol. 46, No. 72, April 15, 1981, EPA Notices, p. 22144). Primarily, CERCLA hazardous waste sites are regulated by EPA under the National Oil and Contingency Plan of 40 CFR Part 300 (USEPA 1983a). Unlike RCRA regulations, the National Oil and Contingency Plan does not provide specific procedures for determining whether a waste is hazardous, or for determining any potential effect on the groundwater at a site. Therefore, RCRA procedures and requirements generally have been employed as guidelines for the current characterization study.

1.2 SCOPE OF THE CHARACTERIZATION

A previous study has surveyed the above-ground structures and most of the facilities at the HRE site, including the soil outside the perimeter of the soil-filled impoundment (S. F. Huang, Environmental and Occupational Safety Division, pers. commun.). The current study commenced in November 1984 and extended through July 1985. The soil backfill in the impoundment was sampled by soil borings and analyzed to determine if it would classify as a hazardous waste as defined by RCRA regulations, and to estimate the radionuclide inventory. The groundwater hydrology at the site was investigated by a review of the site's geology along with the construction and sampling of four groundwater-monitoring wells.

2. DESCRIPTION OF THE IMPOUNDMENT

The HRE facility is located in Melton Valley, approximately 3000 ft (900 m) southeast of the main ORNL complex, as shown in Fig. 1. The soil-filled and capped impoundment is approximately 150 ft

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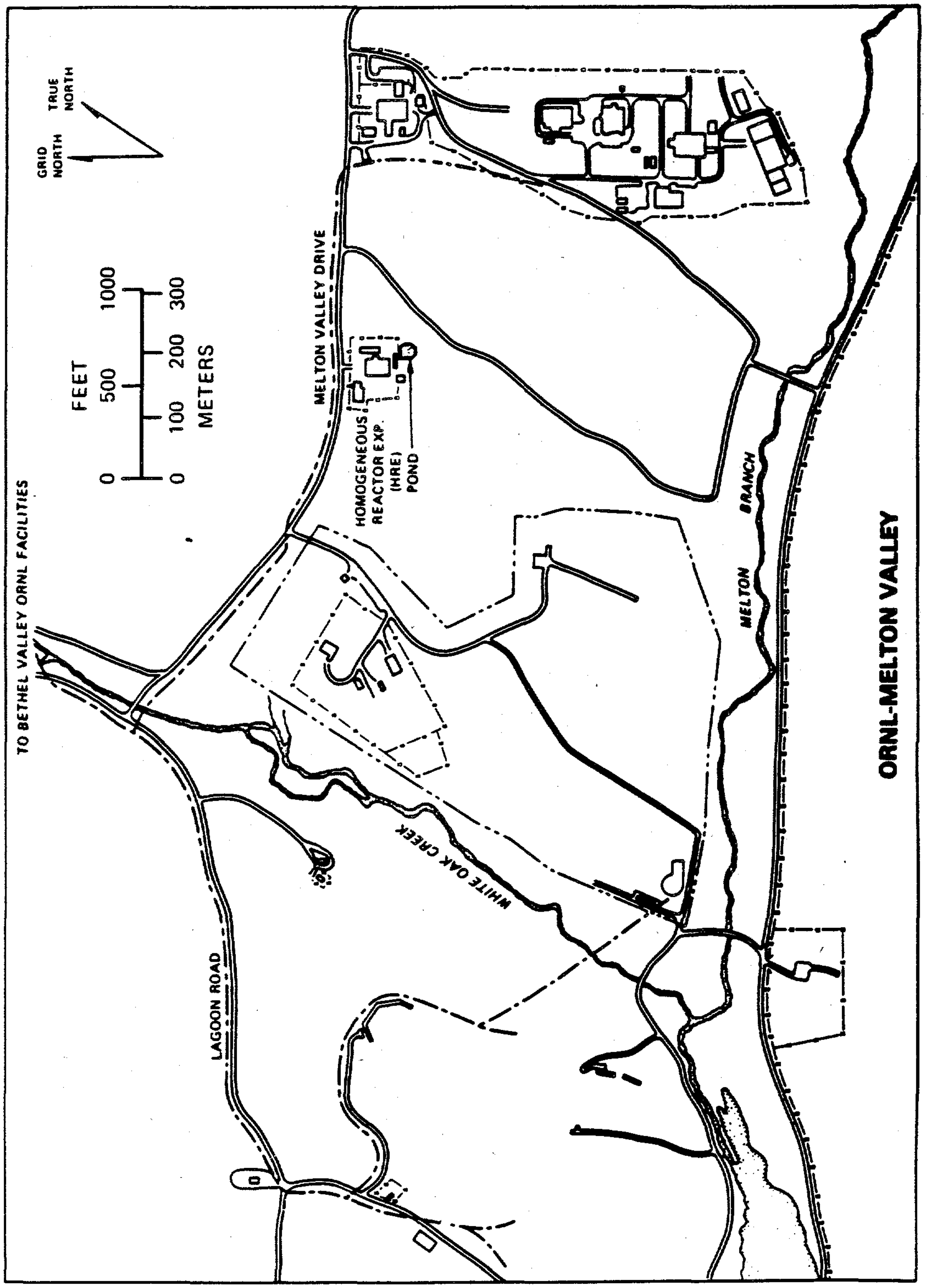

Fig. 1. Location of the Homogeneous Reactor Experiment impoundment within ORNL.

(46 m) south of the several structures related to the reactor experiment that make up the facility complex, as can be seen in Fig. 2. A 12,000-gal (45,000-L) storage tank serving as a reservoir for a radioactivity-decontamination pad is buried less than 50 ft (15 m) northeast of the filled impoundment.

Also, radioactively contaminated equipment is buried in steel barrels on the southwest side. An unnamed stream, a tributary to Melton Branch Creek, flows on the northeast and southeast sides of the impoundment at distances as close as 50 ft (15 m).

2.1 IMPOUNDMENT CONSTRUCTION

The impoundment was constructed as part of HRE in 1955 by excavating into a gentle slope for the west portion and placing earth fill for a dike on the east portion. According to W. R. Reed , Engineering Division, pers. commun., construction dimensions of the bottom of the basin are 45 by 50 ft (14 by 15 m), with sides sloping at 1 vertical on 1.5 horizontal. The bottom of the basin was level, and the maximum height of the lowest portion of the basin perimeter was 10 ft (3-m). Therefore, the maximum capacity of the impoundment was approximately 310,000 gal (1,200,000 L). Reportedly, the pond was partially drained at one time and an asphalt membrane sprayed on the upper slopes of the impoundment. As would be anticipated, no visual signs of asphalt were seen in the samples from borings that penetrated the bottom of the soil-filled impoundment. The outline of the bottom dimensions of the impoundment is shown in Fig. 3.

ORNL PHOTO - 1921-83

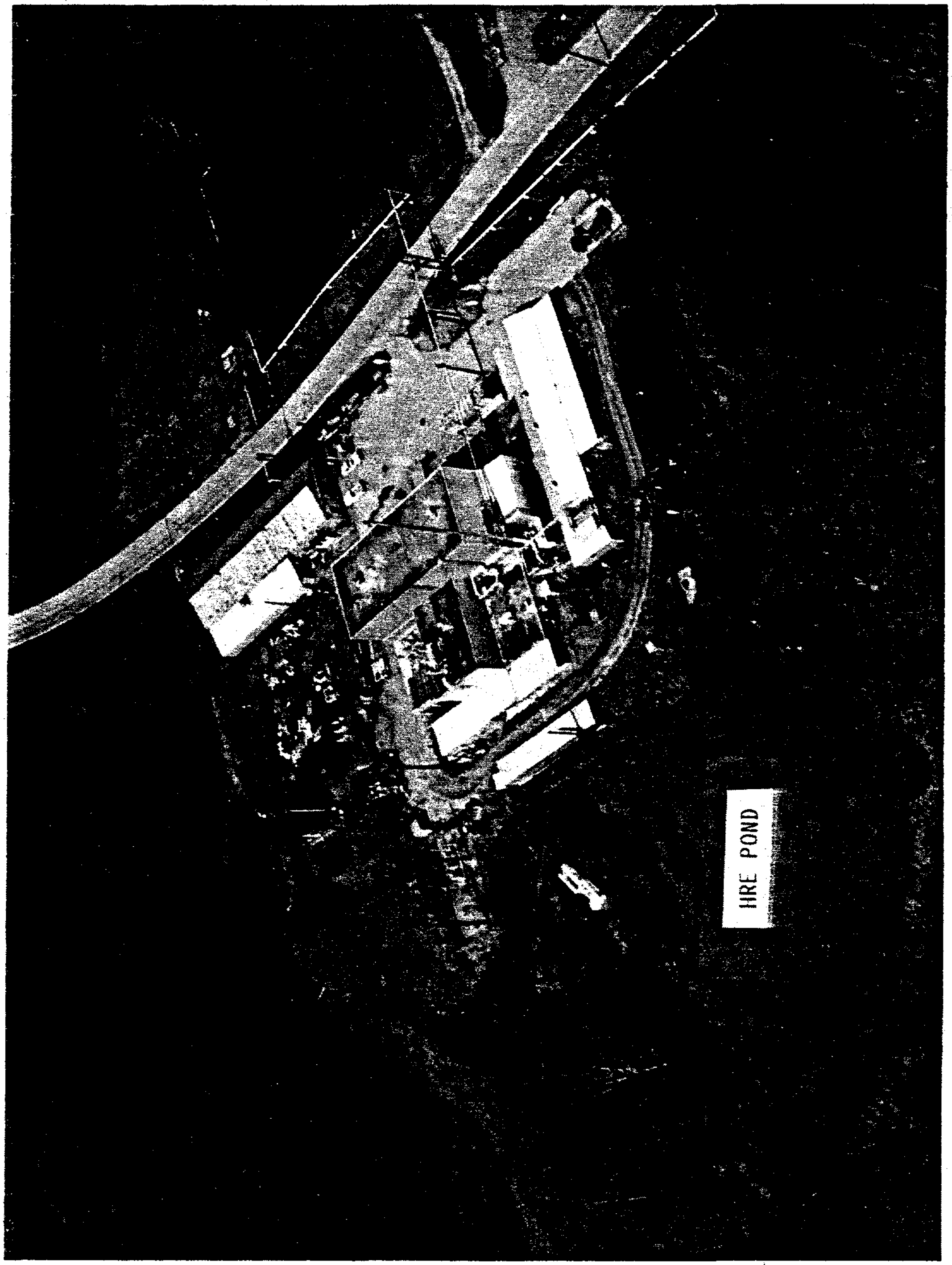

Fig. 2. Aerial photograph of the Homogeneous Reactor Experiment facilities with asphaltic-covered impoundment visible in the lower left.

ORNL-DWG 85-13716C

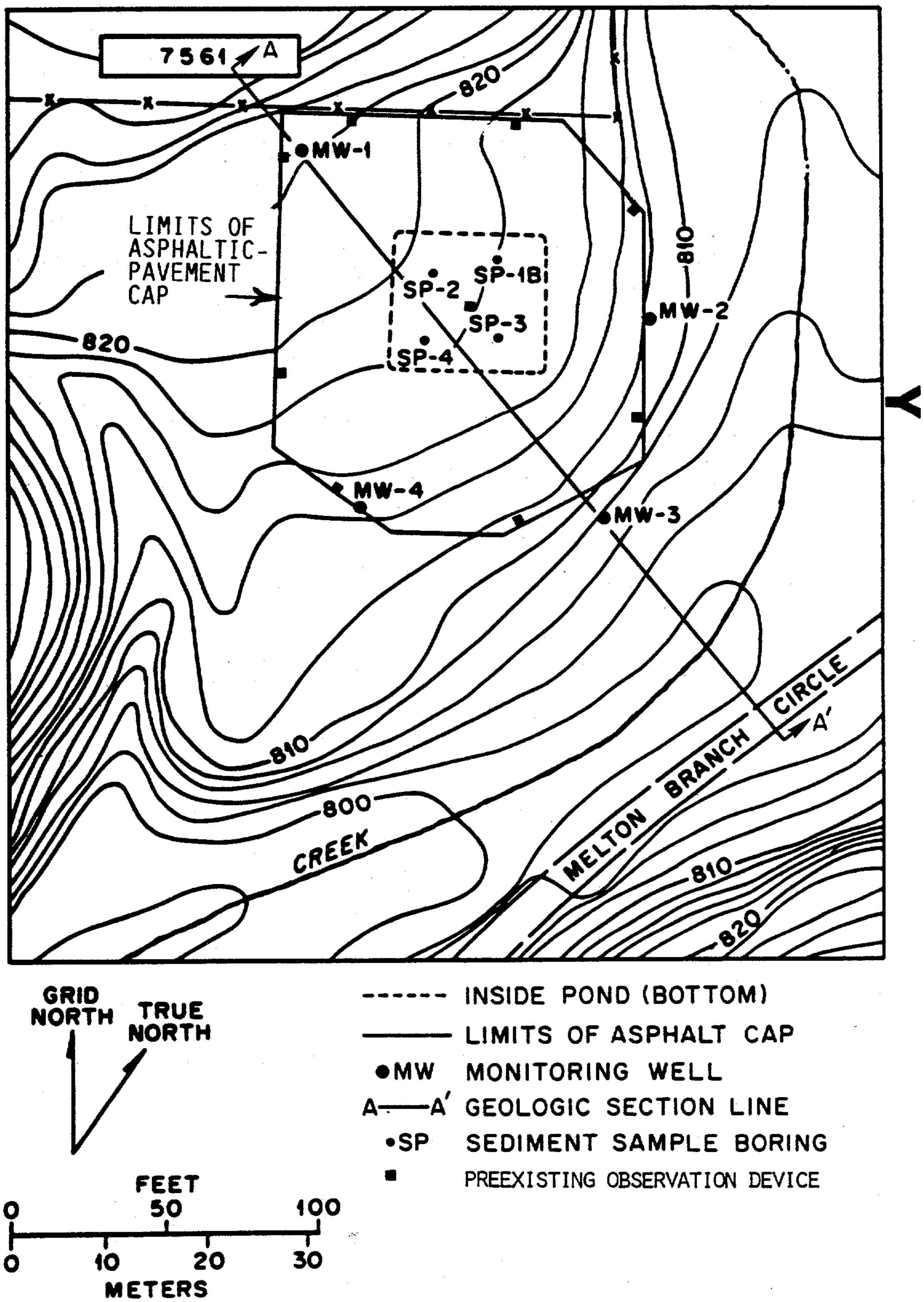

Fig. 3. Location of sampling sites for mixed impoundment fill and sediment waste, and groundwater monitoring wells.

2.2 IMPOUNDMENT OPERATION

The impoundment served as a settling basin for low-level radioactive waste (less than or equal to 1000 cpm/mL) from the HRE. During its operational history, the pond received condensate from an evaporator that was in the process liquid waste system (Myrick 1984) and shield water exposed to the reactor circuits during routine maintenance. Contaminants were caused to settle in the pond by flocculation treatments of ferric flocculants, trisodium phosphate, and diatomaceous earth. Using a floating takeoff, outflow was controlled through a weir box at the end of the effluent line (W. R. Reed, pers. commun.).

ORNL drawing D-36723 shows three influent lines to the impoundment. These lines reportedly entered the impoundment from the northwest side (L. P. Pugh, Operations Division, pers. commun.) and could transfer wastewaters from the following sources: reactor cell sump jets, chemical plant cell B and C sump jets, east valve pit sump jet, reactor heat exchanger blowdown condensate, condensate from the 1000-gal waste condensate tank, and the chemical plant loading pit sump jet (HRE-2 Design Manual, Chapman 1964). Outflow was from the east corner of the impoundment through an 8-in (20 cm) pipeline to a weir box that discharged directly into the unnamed tributary of Melton Branch.

2.3 BACKFILLING OF THE IMPOUNDMENT

The settling basin was operated intermittently from 1957 through 1962. In 1970 the impoundment was closed by filling with soil (containing shale fragments) from a source on the ORNL Reservation. Apparently the fill material was dumped and pushed into the impoundment by bulldozer. The actual depth of the sediment and water in the impoundment at the time of backfilling is not known. W. R. Reed, pers. commun., indicates that an observer to the backfilling operation thought that the impoundment was one-half full of sediment and soil eroded from the side slopes and that the surface of the backfill was dry at the end of the operation. Another knowledgeable source estimated that the pond had accumulated between 1 and 2 ft (0.3 and 0.6 m) of sediment at the time of filling. Approximately 1100 lb (500 kg) of sodium borate weed killer was added to the soil, presumably to the top of the fill. The filled impoundment was then capped with crushed limestone and asphaltic concrete.

Around the perimeter of the cap were driven eight perforated, steel casings that were closed on the bottom end with a pointed drive shoe. Presumably these were to serve as observation devices. An additional device was also driven into the center of the filled impoundment. The approximate locations are shown in Fig. 3. Photographs (ORNL Nos. 1259-71 and 1260-71) of the casings indicate that the perforations were more than 1 in. (2.5 cm) in diameter and spaced several feet (more than a meter) apart in two rows along the length of the casing. Because of their design and construction, the devices are not adequate for use as sampling or observation wells at the present time.

3. MIXED IMPOUNDMENT FILL AND SEDIMENT WASTE

3.1 SAMPLING PROCEDURES FOR MIXED IMPOUNDMENT FILL AND SEDIMENT WASTE

Sampling of the soil-filled impoundment, mixed with sediment waste, was accomplished with a Mobile Model B-33 drilling machine using 8-in. (20.3-cm) in diam. hollow-stem augers and soil-sampling tubes. The locations of the sampling borings are shown in Fig. 3, and record logs of the borings (SP-1 through SP-4) and are provided in Appendix B. Except at the location of boring SP-1B, one boring was conducted at each location. The first two borings drilled at the site, SP-1 and SP-1A, were drilled within 3 ft (1 m) of the location of SP-1B shown in Fig. 3. The depths of the borings ranged from 16 to 17 ft (4.9 to 5.2 m) and bottomed in bedrock at an approximate elevation of 802 ft (244 m). The augers were washed between the drilling of each hole, and the sampling tools were washed in detergent and rinsed with potable water between each sampling event. All drill cuttings and excess samples were placed in barrels for proper disposal as low-level, radioactive waste.

Borings SP-1 and SP-1A were sampled with a split-tube sampler holding a sample with maximum dimensions of 1-1/4 in. (3.2 cm) in diameter and 24 in. (61 cm) in length. This sampler was driven through the hollow-stem auger for either 1- or 2-ft (0.3- or 0.6-m) intervals. The auger was then advanced to the sampled depth and the process continued. In an attempt to increase the percentage of sample recovered, a continuous sampler, manufactured by Central Mining Equipment, Inc. (CME), was employed during the rest of the drilling at the site. However, the sampler required that the boring be advanced to a depth of 5 ft (1.5 m) before it could be inserted within the hollow-stem auger. Above a depth of 5 ft (1.5 m), samples of subsurface materials were obtained from the bit of the auger. Continuous sampling of soil and highly weathered bedrock was possible with this device during penetration by the auger. The sampler was retrieved, and the 2.25-in. (5.7-cm) diam. sample removed every 5 ft (1.5 m) of drill depth.

All soil samples and drill cuttings were monitored with a Geiger-Mueller (G/M) meter, and the maximum radioactivity measured for each sample is shown in the record logs of borings (Appendix B). The highest activity measured with the G/M meter was approximately 100 mR/h at a depth of 6 ft (1.8 m) in boring SP-2. For the most part, the activity measured by the G/M meter was less than 5 mR/h.

Samples obtained in the CME sampler employed in borings SP-1B, 2, 3, and 4 were quartered longitudinally in the field, and a full length quarter from each sample was saved in plastic containers. Samples within each of the above four borings were composited for analysis in the laboratory of the Analytical Chemistry Division, except samples 1 and 2 from borings SP-2 and SP-1B, respectively. These two samples were analyzed separately at a facility that handles materials of elevated levels of radioactivity.

Radioactivity was not measurable with a G/M meter on any drill cuttings or samples from above a depth of 5 ft (1.5 m). From this, it appears that in the backfilling of the pond, the waste sediment was not mixed into the upper portion of the fill. Therefore, only the lower two-thirds of the fill is presumed to be contaminated for inventory calculation purposes.

3.2 SELECTION OF CONSTITUENTS FOR ANALYSES OF MIXED IMPOUNDMENT FILL AND SEDIMENT WASTE

The purpose of the sampling was to determine if the backfill plus sediment of the HRE impoundment would be classified as a hazardous waste under CERCLA or RCRA regulations. Federal regulation 40 CFR 261, promulgated under RCRA, specifies that a solid waste is a hazardous waste if it exhibits any of the defined characteristics of ignitability, corrosivity, reactivity, or extraction procedure (EP) toxicity. The EP toxicity is of primary concern, as the inherent physical and chemical characteristics of the mixed fill/sediment rule out classification as a hazardous waste based on ignitability or reactivity. The EP toxicity characteristic is based on measured concentrations of eight elements of the National Interim Primary Drinking Water Standard (NIPDWS) and six herbicides and pesticides in the filtrate of a 24-h solid waste extraction test (USEPA 1980). If levels of these constituents exceed established maximum permissible concentrations as shown in Table 1, then that waste is considered hazardous.

As supplementary information, concentrations of nonregulatory elements were also reported for EP extracts. These concentrations resulted from analysis of the EP extracts by the multi-elemental analysis technique, Inductively Coupled Plasma (ICP) spectroscopy. These elements, such as Fe, Ca, Na, P, Cu, and Ni, although not

Table 1. Contaminants that determine EP toxicity
(From FR Vol. 45, No. 98, May 19, 1980, p 33122)

<u>Note</u>: Waste is classified as hazardous if concentration of any listed constituent equals or exceeds these maximum concentrations.

EPA hazardous waste number	Contaminant	Maximum concentration (milligrams per liter)
D004	Arsenic	5.0
D005	Barium	100.0
D006	Cadmium	1.0
D007	Chromium	5.0
D008	Lead	5.0
D009	Mercury	0.2
D010	Selenium	1.0
D011	Silver	5.0
D012	Endrin (1,2,3,4,10,10-hexochloro-1,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethano naphthalene)	0.02
D013	Lindane (1,2,3,4,5,6-hexachlorocyclohexane gamma isomer)	0.4
D014	Methoxychlor (1,1,1-Trichloro-2,2-bis [p-methoxyphenyl]ethane)	10.0
D015	Toxaphene ($C_{10}H_{10}Cl_8$, Technical chlorinated camphene, 67-69 percent chlorine)	0.5
D016	2,4-D,(2,4-Dichlorophenoxyacetic acid)	10.0
D017	2,4,5-TP Silvex (2,4,5-Trichlorophenoxy-propionic acid)	1.0

regulated by CERCLA or RCRA, are significant in determining the overall leaching characteristic of the mixed fill/sediment material.

An estimate of total elemental analyses of the HRE impoundment mixed fill/sediment was conducted, and the total concentration of polychlorinated biphenyls (PCBs) was also determined. Analyses of this nature are useful in evaluating remedial action alternatives and are necessary to determine inventories of chemical constituents in the mixed fill/sediment.

The concentrations of certain radionuclides were also determined in the mixed fill/sediment of the HRE impoundment. These included gross alpha and gross beta analyses as well as specific alpha; beta; and gamma-emitting isotopes. Of major concern were ^{90}Sr, ^{137}Cs, ^{60}Co, ^{241}Am, as well as the plutonium and the uranium isotopes. A recent internal report (S. F. Huang, pers. Commun.) also reported measurements of these radionuclides.

3.3 CHEMICAL METHODS USED FOR ANALYSES OF MIXED IMPOUNDMENT FILL AND SEDIMENT WASTE

Chemical analyses used to characterize the mixed fill/sediment were performed by the ORNL Analytical Chemistry Division. The methods used are predominately those described in Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, second edition, published July 1982 by the USEPA Office of Solid Waste and Emergency Response, Washington, DC (USEPA 1982) and Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, revised March 1983, published by USEPA Environmental Monitoring and Support Laboratory, Office of Research and Development, Cincinnati, Ohio (USEPA 1983b).

For the mixed fill/sediment material, the EP toxicity test was conducted as outlined by EPA method 1310 (USEPA 1982). The concentrations of metals in the EP extract were determined by EPA methods 7061, 7081, 7131, 7191, 7421, 7470, 7741, and 7761 in USEPA (1982) and inductively coupled plasma (ICP) spectroscopy, method 200.7 in USEPA (1983b). The concentrations of pesticides and herbicides in the EP extracts were determined by method 8080 (USEPA 1982), except that the analyses were by liquid chromatography instead of gas chromatography.

Total elemental concentrations in the mixed fill/sediment at the HRE impoundment were determined by digesting a 1-g sample (dry weight at 110°C overnight) with a 1:1 mixture of concentrated nitric acid and concentrated hydrofluoric acid. After being brought to dryness, the residue was taken up in 12% nitric acid, and elemental concentrations were determined by ICP spectroscopy. Thus, this digestion procedure precludes the analysis for mercury because the element would have been lost on volatilization. The total concentration of PCBs in the impoundment mixed fill/sediment was determined using method 8080 (USEPA 1982).

3.4 RESULTS AND DISCUSSION OF CHEMICAL ANALYSES OF MIXED IMPOUNDMENT FILL AND SEDIMENT WASTE

As stated earlier, the primary interest in the chemical characterization of the HRE impoundment mixed fill/sediment is the classification of the material as a hazardous or nonhazardous waste. The pH of the fill slurry was found to be 5.6; thus the waste does not have the characteristic of corrosivity as defined by EPA. The controlling test for classification is the EP toxicity characteristic. Concentrations of RCRA regulatory constituents in EP extracts from a composite sample of mixed fill/sediment material taken at various locations within the HRE pond are presented in Table 2. Those constituents measured in the EP extract, but not regulated under RCRA, are presented in Table 1A in Appendix A. The concentrations in tables of Appendix A prefixed by a minus sign are the detection limit for the element or compound for that analysis.

Concentrations of RCRA-regulated constituents in the EP extracts of the composite samples taken from the HRE impoundment mixed fill/sediment are well below maximum allowable RCRA limits, implying that the material would not be considered a hazardous waste based on its EP toxicity characteristic. Concentrations of copper, nickel, and zinc in the EP extracts (Table 1A) are also well below the maximum limit for water in the recently issued "Hazardous Substance Guidelines" (see Table 3) by the state of Tennessee (L. W. Gregory, pers. commun.). Concentrations of radionuclides or PCBs were not measured in the EP extracts.

The elemental concentrations measured in the mixed fill/sediment at the HRE impoundment are listed in Table 2A of Appendix A. Also included are the total concentrations of PCBs measured in the material. The average concentration of PCBs in the four sample borings (SP-1,-2,-3, and -4) was slightly less then 0.2 mg/kg. Lower concentrations were observed in borings SP-3 and SP-4 than in borings at SP-1 and SP-2. Regulatory levels do not presently exist governing total concentrations of inorganic or organic constituents in sediments

Table 2. Concentrations of RCRA regulated constituents in EP extracts from HRE impoundment fill/sediment

Constituent	Unit	Maximum allowable concentration	Location	Sample date	Measured concentration mean
As	mg/L	5.0	Composite	03/06/85	-0.0001
Ba	mg/L	100.0	Composite	03/06/85	0.6800
Cd	mg/L	1.0	Composite	03/06/85	0.0650
Cr	mg/L	5.0	Composite	03/06/85	0.0360
Pb	mg/L	5.0	Composite	03/06/85	-0.0001
Hg	mg/L	0.2	Composite	03/06/85	0.0061
Se	mg/L	1.0	Composite	03/06/85	-0.0001
Ag	mg/L	5.0	Composite	03/06/85	-0.0001
Endrin	mg/L	0.02	Composite	03/06/85	-0.0001
Lindane	mg/L	0.04	Composite	03/06/85	-0.0001
Methoxychlor	mg/L	10.0	Composite	03/06/85	-0.0001
Toxaphene	mg/L	0.5	Composite	03/06/85	-0.0001
2,4-D	mg/L	10.0	Composite	03/06/85	-0.0001
2,4,5-TP	mg/L	1.0	Composite	03/06/85	>0.0001

Table 3. Hazardous substance guidelines
Tennessee Division of Solid Waste Management - Superfund

Compound	Maximum limit, water ppm or mg/L	Maximum limit, soil ppm or mg/kg	Water reference
Benzene	0.025	2.5	6
Ethylbenzene	1.4	140	1
Toluene	14.3	1430	1
Carbon tetrachloride	0.025	2.5	6
Chloroform	0.002	0.2	1
1,2-Dichloroethane	0.26	26	6
1,1-Dichloroethylene	0.35	35	6
Methylene chloride	0.15	15	2
Tetrachloroethylene	0.085	8.5	6
Trichloroethylene	0.26	26.0	6
1,1,1-Trichlorethane	1.0	100	6
Acetone	20	2,000	7
Ethylacetate	400	40,000	4
Xylenes	0.62	62	2
Methyl ethyl ketone	0.75	75	5
Methyl isobutyl ketone	100	10,000	4
Vinyl chloride	0.06	6.0	6
Naphthalene	0.025	2.0	1
Di-n-butyl phthalate	0.034	3.4	1
Pentachlorophenol	1.01	101	1
Cyanide	0.2	10	3,8
Phenol	0.3	30	1,8
Copper	1	100	3
Zinc	5	500	3,8
Nickel	0.2	20	3,8
Mercury	0.002	0.2	3,8
Arsenic	0.05	5	3,8
Cadmium	0.01	1.0	3,8
Chromium	0.05	5	3,8
Silver	0.05	5	3,8
Lead	0.05	5	3,8
PAHs	0.000028	0.0028	1
PCBs	0.00000079	0.000079	

Water limits, clarified by MED 8/28/84:
  Nitrates(N) - 10 ppm
  Sulfates - 250 ppm
  Phosphate - should be set below 50 ppm in water (gives renal damage in rats, is 10 times dietary, adequate nutritional level for rats)

References:
1. Federal Register, 45:231, Nov. 1980
2. Long-term SNARL
3. Interim Drinking Water Standard
4. Dangerous Properties of Industrial Materials, N. Irving Sax
5. 10-day SNARL
6. Federal Register, 49:114, 24338, June 1984
7. Flash point concentration
8. E.P. Toxicity Limit or suggested level (phenol, cyanide, nickel)

or such fill materials. The concentration of PCBs, however, exceeds the maximum soil limit listed by the Tennessee Hazardous Substance Guidelines. Concentrations of chromium also exceed the suggested guideline for soil; that is, the average concentration in the four borings was slightly greater than 90 mg/kg as compared with the recommended guideline of 5 mg/kg. Two of the borings (SP-1 and SP-2) contained approximately 3 mg/kg of cadmium, while analysis of the other two borings, (SP-3 and SP-4) cadmium was not detected at 0.0001 mg/kg. The guideline for cadmium in soil is 5 mg/kg. It is not presently clear why the SP-1 and SP-2 borings contained the elevated levels of cadmium as compared with the SP-3 and SP-4 borings. This pattern was not evident with respect to the distribution of the other elements. However, the concentration of ^{137}Cs and ^{90}Sr, discussed in Sect. 3.6 later, did show a similar distribution pattern. The concentration of nickel (average concentration of approximately 40 mg/kg) in the fill/sediment mixture also exceeded the soil maximum limit (20 mg/kg) outlined in the Tennessee Hazardous Substance Guidelines. However, concentrations of arsenic, copper, lead, and zinc in the fill material were well below the soil limits (compare concentrations in Table 2A in Appendix A to those listed in Table 3). The total concentration of mercury in the fill/sediment mixture was not determined.

The total inventory in the fill/sediment mixture was determined using an average concentration of each element or compound from the four borings. The measured bulk density of this material was quite high (2.1 kg/L). The average water content, on a wet weight basis, was determined to be 21% for the four borings. The total volume of mixed fill/sediment was estimated to be 2.1×10^6 L. Using these parameters, the total inventory of each of the measured constituents was determined (see Table 3A in Appendix A). Total PCBs in the waste was estimated to be less than 1 kg.

3.5 RADIOACTIVITY ANALYTICAL METHODS

Concentrations of radionuclides in the HRE impoundment mixed fill/sediment were determined using solid state alpha and beta detectors following dissolution of the sample by concentrated nitric and hydrofluoric acids as described above. Strontium-90 was separated from the other cations by precipitation as the oxalate salt and then counted on a beta proportional counting system. Gross alpha and gross beta measurements were performed by counting on Tennelec LB5100 Series II equipment. This automated system is programmed to convert raw data to activity units as well as to utilize material weights or volume to produce activity per unit (weight or volume). Analyses of gamma-emitting radionuclides were conducted directly (without chemical dissolution) using high-resolution germanium detectors. The detectors were shielded from extraneous background and were calibrated for the respective sample geometries using certified mixtures of gamma-emitting radionuclide standard solutions from the National Bureau of Standards (NBS). Calibration procedures and assessment have been described elsewhere (Larsen and Cutshall 1981).

3.6 RESULTS AND DISCUSSION OF RADIOACTIVITY ANALYSES OF THE HRE IMPOUNDMENT FILL AND SEDIMENT WASTE

The radioactivity in the mixed fill/sediment waste was predominantly that of ^{90}Sr and ^{137}Cs (see Table 4A in Appendix A). For this sampling, borings SP-1B and SP-2 were subsampled at two depths. These subsamplings were conducted based on G/M meter readings. The samples SP-1BH and SP-2H showed much higher radioactivity, and thus these subsamples were analyzed separately from the remainder of the same boring. The subsample SP-1BH represented approximately 20% of the total core, while SP-1B constituted the remaining 80%. With respect to the SP-2 boring, the SP-2H subsample represented approximately 40% of the core and the subsample SP-2, approximately 60%. Table 4A illustrates the much higher activity of ^{90}Sr and ^{137}Cs in the SP-1BH and SP-2H samples. Also note the much higher concentrations of ^{90}Sr and ^{137}Cs in the SP-1B and SP-2 borings as compared with the SP-3 and SP-4 borings. A similar distribution pattern was noted for cadmium in these borings (see Sect. 3.4). Very low concentrations of alpha-emitting radionuclides were detected in this waste (note the low concentration of gross alpha as well as individual measurements of plutonium and uranium isotopes). The highest levels of activity were found in samples SP-1BH and SP-2H. It is unclear why the level of gross beta in sample SP-1BH was low compared with the level of ^{90}Sr determined in the same sample. The opposite relationship was observed in the SP-2H sample; the gross beta was 20 times the ^{90}Sr concentration. In fact, across all of the soil/sediment samples counted, the ratios of gross beta to ^{90}Sr

Table 4. Inventory of radionuclides
in HRE impoundment fill/sediment

Constituent	Total inventory	
	GBq	CI
Gross-alpha	<0.001	<0.001
Gross-beta	27600	750
^{137}Cs	604	16
^{234}U	0.123	0.003
^{235}U	0.017	<0.001
^{238}Pu	<0.001	<0.002
^{238}U	0.079	0.002
^{239}Pu	0.005	<0.002
^{241}Am	0.001	<0.001
^{60}Co	0.062	0.002
^{60}Sr	2750	75

ranged from 0.48 to 27. The error associated with the direct counting of solid samples for gross beta is considerable compared with the determination for ^{90}Sr. For example, the ^{90}Sr determinations were carried out following dissolution of the samples with a 1:1 mixture of concentrated nitric acid and concentrated hydrofluoric acid. Strontium was separated from the matrix elements of the sample by precipitation of the oxalate salt and then counted on a beta proportional counting system. Gross beta determinations, however, were made directly on the solid or on the residual following dissolution by acid digestion, which introduces considerable error with regard to self-adsorption, etc. For this reason, the measurements for gross beta are not considered to be as accurate as those for ^{90}Sr. Analyses of the fill/sediment mixture for ^{134}Cs and ^{154}Eu were below the detection level of 0.0001 Bq/g (these data are not included in Table 4A).

The inventory of radionuclides in the fill/sediment mix was determined using the same input parameters for determining the total inventory of inorganic and organic constituents (2.1 kg/L bulk density, 21% water, and 2.1 x 10^6 L total volume). However, in this case, a weighted mean concentration based on the previously described volume distribution of the subsamples in each of the cores was used for borings SP-1B and SP-2. The inventory (Table 4) showed a preponderance of ^{90}Sr and ^{137}Cs over alpha-emitting radionuclides.

4. SUBSURFACE EXPLORATION AND MONITORING WELLS

4.1 DRILLING AND SAMPLING

Five borings ranging in depth from 10 to 30 ft (3 to 9 m) were drilled for four monitoring wells with a Mobile Model B-33 drilling machine using 8-in. (20.3-cm) diam. hollow-stem augers. The augers were washed between the drilling of each hole, and the sampling tools were washed between each sampling event.

Samples were taken with the CME sampler. When the drill could no longer advance the auger by employing the sampling device, the sampler was removed and replaced by the center section of the auger bit, which allowed the drilling to continue in firm rock. All soil samples and drill cuttings were monitored with a G/M meter. At a depth of 8.5 ft (2.6 m) boring MW-4 measured 1000 cpm on the G/M (approximately 0.3 mR/h). The boring was terminated at that depth to prevent the possibility of radioactive groundwater being brought to the surface. Boring MW-4A was drilled within 3 ft (0.9 m) of MW-4, and was completed as monitoring well 4. Boring MW-4 was left open and diked during the drilling of MW-4A so that it would receive any groundwater brought up by the auger from boring MW-4A. Drill cuttings from borings MW-4 and MW-4A were placed in barrels and disposed of as low-level radioactive waste. Descriptive records of all borings are provided in the boring logs in Appendix B. Locations of the borings (as monitoring wells) are shown in Fig. 3.

4.2 MONITORING WELL CONSTRUCTION

A groundwater monitoring well was constructed in each of the borings, except boring MW-4, using 3-in. (7.6-cm) diam. fiberglass well screen and casing. The entrance areas of the well screens consisted of two rows of slots with 0.01-in. (0.25-mm) wide openings. The screens were 10 ft (3 m) long and were surrounded by a sand pack of medium-grained quartz sand that extended a minimum height of 1 ft (30.5 cm) above the top of the well screen. A bentonite (clay) seal of at least 1 ft (30.5 m) minimum thickness was placed at the top of the sand pack. The remainder of the boring was backfilled with portland cement concrete from the top of the seal to the top of the boring. A 4-in. (10.16-cm) diam. protective casing, 5 ft (1.52 m) long, was installed around the well-riser pipe, with both the pipe and casing extending approximately 3 ft (0.91 m) above the ground surface. The top of the riser pipe is closed by a removable, plastic cap. Construction details of each of the wells are provided in Appendix C. A summary of construction details and measured groundwater elevations, as well as surveyed locations and elevations, is provided in Table 5.

4.3 MONITORING WELL LOCATIONS

The location for monitoring well 1 (MW-1) was selected in an attempt to provide a groundwater sampling point located upgradient (i.e., in the direction of increasing static head of the groundwater table) of the impoundment from which representative samples of the groundwater that will move through the impoundment site could be

Table 5. Summary of monitoring well location, construction data, and water levels at the HRE impoundment

Parameter	MW-1	MW-2	MW-3	MW-4
North grid coordinate (ft)	18634.87	18581.39	18518.64	18515.45
East grid coordinate (ft)	31422.87	31533.62	31525.86	31444.65
Top of well casing el. (ft)	827.03	815.71	810.81	816.10
Height of casing aboveground (ft)	3.8	2.3	2.7	3.0
Ground surface el. (ft)	823.2	813.4	808.1	813.1
Top of well screen el. (ft)	807.0	800.7	795.8	804.4
Bottom of well screen el. (ft)	797.0	790.7	785.8	794.4
Top of sand pack el. (ft)	815.2	805.4	800.1	805.1
Bottom of well hole el. (ft)	793.5	788.5	783.4	788.4
Diameter of well pipe/screen (in.)	3.0	3.0	3.0	3.0
Type material of pipe/screen	fiber glass	fiber glass	fiber glass	fiber glass
Width of screen opening (in.)	0.01	0.01	0.01	0.01
Water level el. (ft) 4-8-85	814.79	808.20	803.95	805.34
Water level el. (ft) 5-23-85	813.58	807.44	803.40	805.50
Water level el. (ft) 6-4-85	813.64	806.97	803.26	805.35
Water level el. (ft) 7-1-85	815.32	808.10	803.95	805.37

obtained. Also, the upgradient well should not be affected by potential contamination from the monitored facility. The location of MW-1 was restricted by buried radioactively contaminated materials on the southwest, and above- and below-ground structures on the west.

The locations of the other three monitoring wells were selected to determine if contaminants from the impoundment are migrating into the groundwater. Further, no well was located within the area enclosed by the asphaltic-pavement cap, as reports indicate that accurate boundaries of the eroded slopes of the impoundment are not known. Therefore, the limits of the cap were considered to be the limits of the impoundment. As CERCLA does not provide specific requirements for monitoring well locations, these wells comply with regulations promulgated in accordance with RCRA which specify that there be at least three hydraulically downgradient (i.e., in the direction of decreasing static head of the groundwater table) wells. These downgradient wells are required to be at the boundary of the impoundment facility, which, as described in RCRA Permit Writer's Manual Groundwater Protection 40 CFR, Part 264, Subpart E, Draft (USEPA 1983c), EPA interprets to be no more distant than the outside toe of any containment dike that may exist, plus 30 ft (9.14 m) for physically selecting an appropriate drill site.

Monitoring well 2 is located approximately along the regional geologic strike of the bedrock strata between the filled impoundment and the southeast section of the adjacent stream. Relative to the impoundment, monitoring wells 3 and 4 are located down-dip of the regional geologic strike of the bedrock strata. They are also between the impoundment and the south- and southwest-flowing sections of the adjacent stream.

4.4 SURFACE GEOPHYSICAL SURVEY

An electromagnetic (EM) conductivity survey, using a model EM-34 instrument manufactured by Geonics Ltd., was conducted around the perimeter of the HRE impoundment. This geophysical method provides a rapid site reconnaissance that can detect contaminant plumes of high ionic strength. The technique measures the apparent electrical conductivity of the subsurface using self-contained dipole transmitter and receiver coils held in the horizontal dipole configuration and separated by a horizontal distance of 20 ft (6.1 m). In this configuration, the instrument senses to approximately 0.75 of the intercoil spacing (Geonics 1983). Therefore, the apparent conductivity was measured in units of millimhos per meter (mmhos/m) to an approximate depth of 15 ft (4.6 m) at each station. Readings in mmhos/m at each measurement station around the HRE impoundment are shown in Fig 4. The magnitude of the variations does not seem to indicate major conductivity anomalies that would be attributable to contamination plumes from the impoundment.

5. GEOLOGY

5.1 REGIONAL GEOLOGY

Oak Ridge National Laboratory lies in the Ridge and Valley Physiographic Province. In Tennessee, the province consists of northeast-southwest striking rock strata of limestone, sandstone, and

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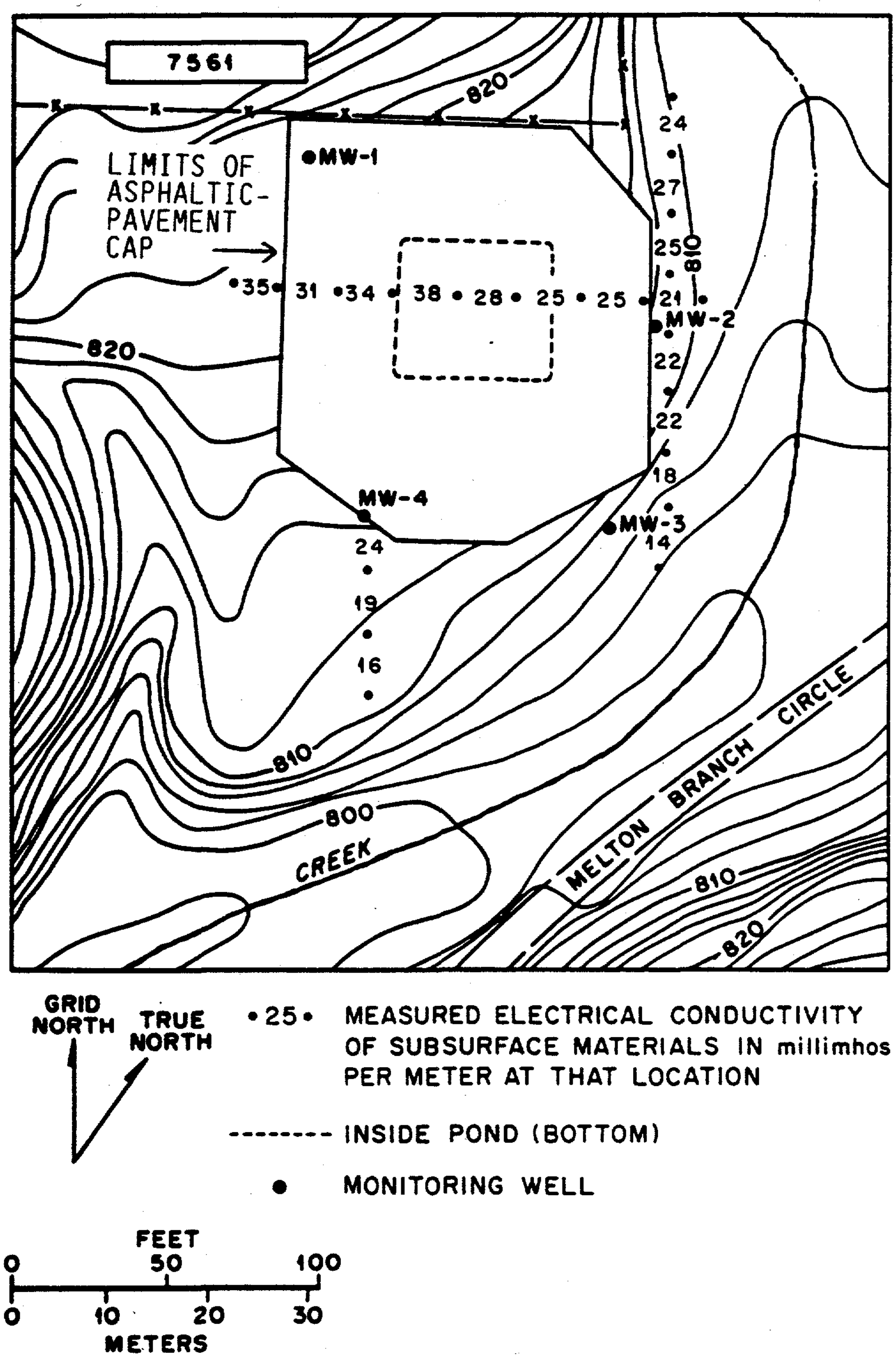

Fig. 4. Locations and measurements of electromagnetic conductivity survey.

shale extending from the Georgia-Alabama border on the south to the Virginia border on the north. The strata is tilted to angles of 30 degrees and greater throughout its length, resulting in the erosion-resistant beds forming parallel ridges, and those less resistant beds becoming intervening valley floors.

5.2 Site Geology

5.2.1 Bedrock

The HRE impoundment lies in Melton Valley approximately 2000 ft (600 m) southeast of the Copper Creek fault. As shown on the geologic map of Fig. 5, the site is underlain by unit "Ccb" of the Conasauga Group. The lithology of this unit is described by McMaster and Waller (1965) as follows:

> Variable lithology, ranging from shale and siltstone to limestone. Limestone is characteristically pebble conglomerate or edgewise conglomerate having irregular bedding surfaces coated with thin film of dark grey clay and marked by abundant ropy 'worm trails'. Limestone occurs in zones of shale and siltstone. Siltstone in this unit is commonly calcareous and white or light grey when fresh. Shale is thinly bedded, colored brown, olive, and tan, and locally maroon. In places the unit is deformed by very small, sharp folds and faults of small displacement.

They describe the residual material as:

> Unit weathers to a bedded shale appearance, leaving little or no indication of original calcareous nature. Limestone weathers to porous brown siltstone or to a light orange-yellow illitic clay. Residuum is generally light tan to yellow-brown but local variations include maroon and green bands. Black manganese oxide stains common on joint surfaces.

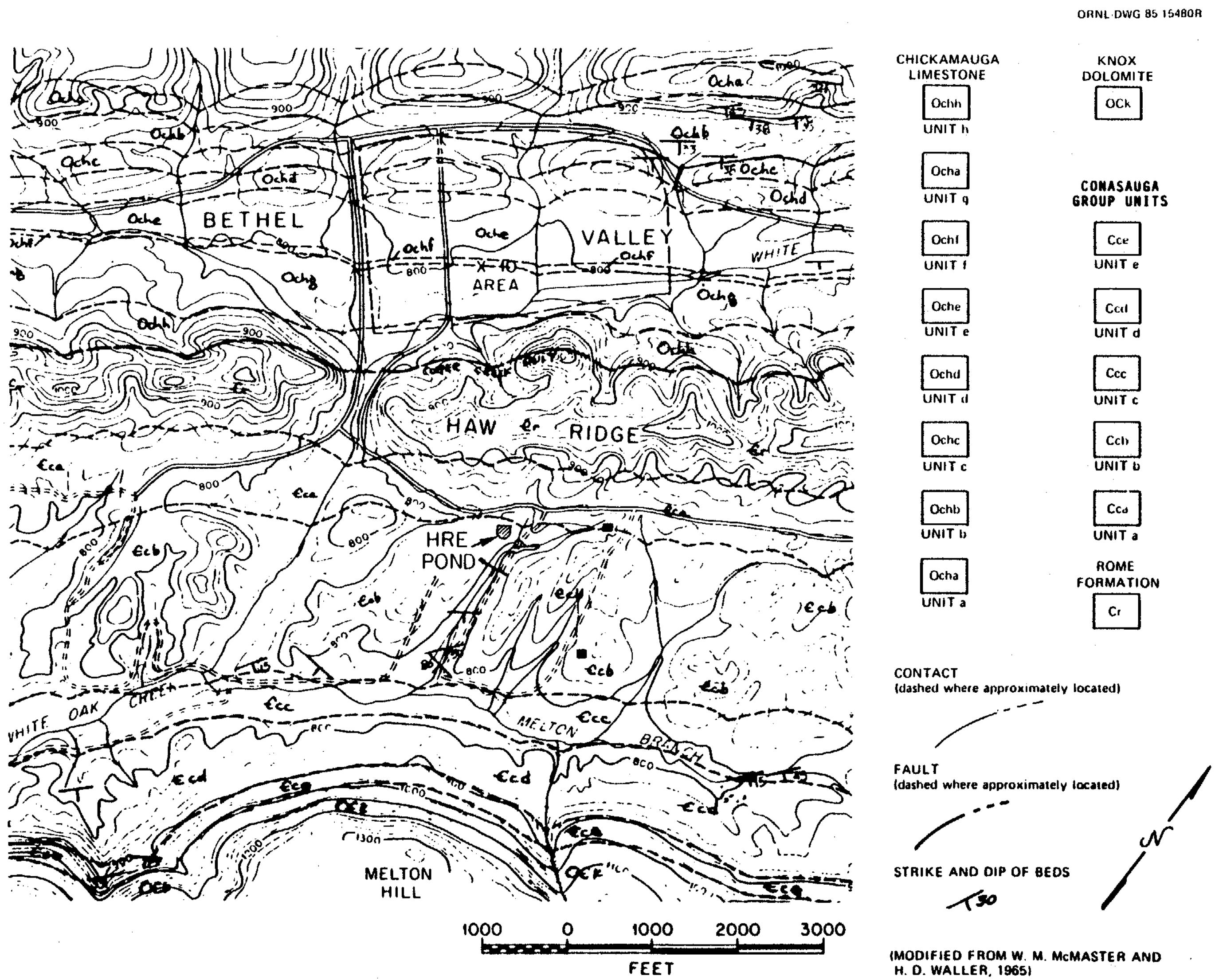

Fig. 5. Geologic map of the ORNL area including the Homogeneous Reactor Experiment impoundment.

The HRE impoundment was constructed in the lower beds of the Ccb unit and less than 100 ft (30 m) from the surface expression of the contact of units Ccb and Cca, as mapped by McMaster and Waller (1965). The strike of this contact, as measured from the geologic map shown in Fig. 5, is approximately north, 60 degrees east.

From later work in the area (Haase, Zucker, and Stow 1985; Rothschild et al. 1984) it appears that the lower strata in unit Ccb, as mapped by McMaster and Waller (1965), likely consists of, in ascending order, the Rutledge Limestone and Rogersville Shale formations.

A geologic section through the impoundment is shown in Fig. 6. The sideslopes of the filled impoundment shown in this figure are theoretical slopes based on the design slope of 1 vertical on 1.5 horizontal. Due to reported erosion during the operating life of the impoundment, it is likely that the actual slopes deviate from the configuration shown in Fig. 6.

5.2.2 Soil

The soil thickness encountered in the borings for the monitoring wells ranged from less than 1 ft (0.3 m) for MW-1 and -4, to as much as 5 and 9 ft (1.5 and 2.7 m) for MW-2 and -3, respectively. Some of the soil may be material that was excavated from the impoundment during construction and used as fill. As indicated by the boring records in Appendix B, the soil consists of material which would classify as clay under the Unified Soil Classification System. According to McMaster and Waller (1965), soils derived from the Conasauga Group contain illite and vermiculite as the predominant clay minerals.

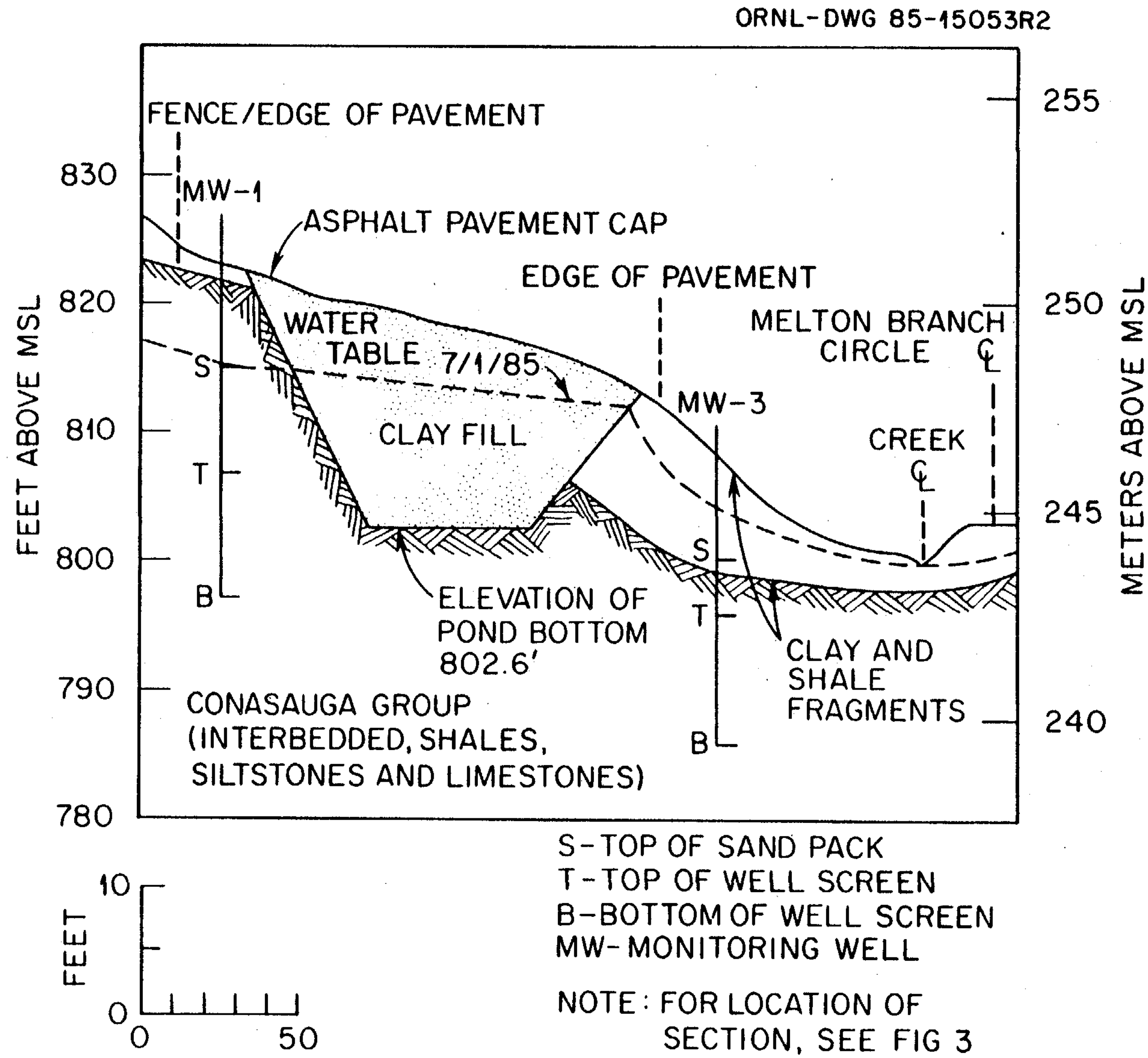

Fig. 6. Geologic section through the Homogeneous Reactor Experiment impoundment.

6. HYDROLOGY

From 1948 through 1983, the mean annual precipitation at Oak Ridge was 54.61 in (138.71 cm). In this region, the heaviest precipitation normally occurs during winter and early spring, with the monthly maximum normally occurring during the period January to March. However, during some years the monthly maximum has occurred in July because of thunderstorms. September and October are usually the driest months. According to the "Climatic Atlas of the United States" (U.S. Department of Commerce, 1979), mean annual lake evaporation in the Oak Ridge area is 33 in. (88.9 cm).

After cessation of operation of the pond in 1962, and prior to its filling with soil in 1970, it is uncertain how to account for the 22 in. (56 cm) of net annual precipitation input to the pond. If there were no releases, it would have been added to the groundwater through infiltration from the pond. One person recalls seeing very little water in the pond after operations ceased, and cattails growing in the bottom.

6.1 GROUNDWATER MOVEMENT

A water-table map of the site is shown in Fig. 7. The map is based on water-level observations from the four monitoring wells constructed during this study (Table 5), on water levels encountered in the borings conducted for the purpose of sampling the soil/sediment (Appendix B), and on measurements made in September 1985 by the old observation devices shown in Fig. 3. The water-level measurements made in the old observation devices have to be used with a good deal of

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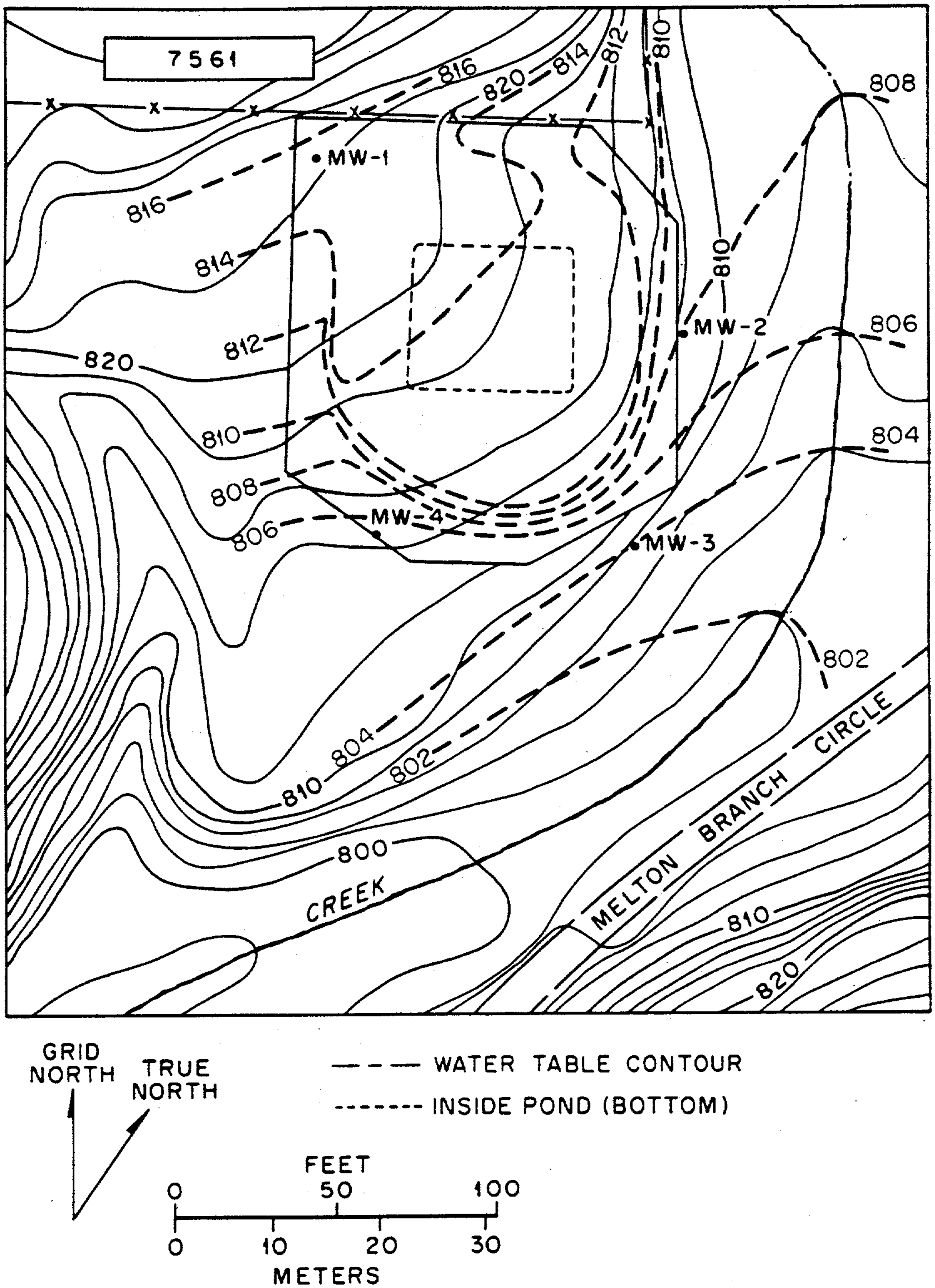

Fig. 7. Water-table map of the Homogeneous Reactor Experiment impoundment.

judgment as they may not be representative of the piezometric surface due to their construction (Sect. 2). The map shows the hydraulic gradient at the impoundment to be generally towards the creek that partially encircles the impoundment.

As shown in the geologic section (Fig. 6) through the pond, and the water-table map (Fig. 7), the water table is fairly uniform across the filled impoundment and is approximately 10 ft (3 m) above the bottom elevation.

Studies on the ORNL reservation (Webster 1976, Davis et al. 1984, and Rothschild et al. 1984) result in the observation that in the bedrock the direction of groundwater movement is greatly affected by the directional permeability of the strata. The Conasauga strata is anisotropic in respect to hydraulic conductivity, with conductivities parallel to the direction of geologic strike being reported as 3 to 20 higher than in a direction normal to strike. Therefore, the overall groundwater movement through the bedrock is often in a direction at some acute angle to the groundwater contours. Such movement would not normally be expected to be in a straight line of flow, but rather would follow irregular pathways along joints and bedding planes because the bedrock strata has insignificant primary permeability.

6.2 UPPERMOST AQUIFER

The soil at the impoundment consists of material that has been visually classified as clay (according to the Unified Soils Classification System), which categorically has low hydraulic conductivities. The uppermost aquifer at the site is the "Ccb" unit (possibly either the Rutledge or Rogersville formations). Davis et al. (1984) conducted hydraulic conductivity tests in 36 monitoring wells in the Maryville Limestone of the Conasauga Group. Conductivities ranged from 1×10^{-5} to 238×10^{-5} cm/s, with a geometrical mean of 6.31×10^{-5} cm/s, and the effective porosity was estimated to be 0.03. Rothschild et al. (1984), at a site approximately 3500 ft (1000 m) distant along geologic strike, tested the conductivity in 12 wells in the Conasauga. The geometric mean of these tests was 2.57×10^{-5}. These aquifer parameters are believed to be representative of the HRE site.

6.3 GROUNDWATER SAMPLING METHODS

Water levels were measured with an electric tape prior to purging and sampling each well, and the immersed portion of the tape was rinsed with distilled water between wells. The wells were sampled with bottom loading, stainless steel bailers that were disassembled for thorough cleaning before use. The bailers were washed with hot water and detergent, and rinsed with distilled water. In addition, during the first round of sampling, the bailers were also rinsed with dilute nitric acid followed by distilled water. During the second round, to avoid rusting of the steel, the dilute acid rinse was replaced with alcohol. A new nylon line was attached to the bailer for each well.

No water was introduced into the wells during drilling, and the first round of samples was taken without purging the wells. All the wells were sampled within one to seven days after completion of drilling. This step was taken because there was no adjacent, open impoundment to which water obtained from the purging operation could be returned (as is customary); and facilities were not immediately available to dispose of the water properly otherwise. Prior to taking a sample during the second round of sampling, the well was purged by removing a volume of water equal to at least three times the volume contained within the well screen and casing. This amounts to a volume of 1.1 gal/ft (4.2 L/0.3 m) of water depth in the well. The water removed for purging purposes was measured in 5-gal (19-L) containers and collected in 55-gal (210-L) barrels. In total, 400 gal (1500 L) was purged from the wells and trucked to the process waste system for disposal.

6.4. SAMPLE COLLECTION AND PRESERVATION

Groundwater samples to be analyzed by the Analytical Chemistry Division (ACD) were poured directly from the stainless steel bailer into new glass, 1-qt (0.95-L) containers (previously rinsed with distilled water) with Teflon-lined caps. Four such samples were collected from each well during February (March for MW-4) and May 1985, and two of the samples from each were acidified with nitric acid to a pH of 2. These samples were either delivered to the Analytical Chemistry Division within 1 h after collection, where they were refrigerated, or were stored overnight in a refrigerator for next-day delivery to ACD. In addition, in February and May, 1-L samples were collected from each well and placed in plastic containers for gamma radiation analysis by Environmental Sciences Division's Low-Level Gamma-Ray Spectrometry Laboratory using a high-resolution, lithium-drifted germanium [Ge(Li)] detector. These samples required no preservation. Specific conductivity and pH were measured at the well site at the time of sampling.

6.5 CHAIN OF CUSTODY

A record was completed for all samples collected which contains the following information: name of collector, identifying list of samples, date and location where collected, inclusive dates that samples were in the collector's custody, and the date that samples were transferred to the laboratory for analyses. A copy of this record accompanied the samples to the laboratory.

6.6 SELECTION OF CONSTITUENTS FOR ANALYSIS IN GROUNDWATER

The principal goal in analyzing groundwater was to determine if the groundwater had been contaminated. To do this the groundwater was analyzed for those 30 constituents promulgated under RCRA regulations, as shown in Table 6. For active hazardous waste facilities (those that receive wastes after November 19, 1980), RCRA regulations require that each groundwater monitoring well be sampled and analyzed for these constituents at least four times during the first year to ascertain any seasonal variations in groundwater quality. Sampling for this report was conducted in February (March for MW-4) and May 1985.

In addition to those 30 constituents listed in Table 6, groundwater samples were analyzed by ICP spectroscopy. This technique provides general information on concentrations of nearly 30 elements in one analysis. Many of these are not RCRA regulatory elements, but their

Table 6. RCRA - 40 CFR 265.92 - Groundwater monitoring parameters

EPA Interim Primary Drinking Water Standards

Parameter	Maximum level (mg/L)
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Fluoride	1.4-2.4
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.
Selenium	0.01
Silver	0.05
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4-D	0.1
2,4,5-TP Silvex	0.01
Radium	5 pCi/L
Gross Alpha	15 pCi/L
Gross Beta	4mR/y
Coliform Bacteria	1/100mL

Parameters establishing groundwater quality:

Chloride
Iron
Manganese
Phenols
Sodium
Sulfate

Parameters used as indicators of groundwater contamination:

pH
Specific Conductance
Total Organic Carbon
Total Organic Halogen

concentrations in groundwater are useful in evaluating general groundwater quality. For instance, the concentrations of copper, nickel, and zinc were determined in groundwater samples using this technique. These elements are included in the list of compounds and elements listed in the recently issued "Hazardous Substance Guidelines" by the State of Tennessee (L. W. Gregory, pers. commun.). Groundwater samples were also analyzed for PCBs and the radioisotopes ^{90}Sr, ^{137}Cs, and tritium.

6.7 CHEMICAL METHODS USED FOR ANALYSIS OF GROUNDWATER

The methods used to analyze groundwater are those described in USEPA (1982 and 1983b). For elemental concentrations of the NIPDWS, it was necessary to use atomic absorption methods to reach the required detection levels. The recommended USEPA methods are 7061, 7081, 7131, 7191, 7421, 7470, 7741, and 7761 for As, Ba, Cd, Cr, Pb, Hg, Se, and Ag, respectively. ICP spectroscopy (method 200.7 in USEPA 1983b) was also used to determine concentrations of nonregulatory elements. The concentrations of pesticides and herbicides, as well as the PCBs in the groundwater, were determined by method 8080 (USEPA 1982), except that the analyses were by liquid chromatography instead of gas chromatography. The total toxic organics (TTO) were determined using method 624 (USEPA 1983b) or pentane extraction for the volatile organic compounds and method 1625 (USEPA 1982) for the semivolatile compounds. Coliform bacteria were determined by method 405.1 (USEPA 1983b). Concentrations of fluoride, chloride, nitrate, and sulfate were determined using methods 340.2 and 300.0 as described in USEPA (1983b). Phenol concentration was determined by method 420.1 (USEPA 1983b). Total organic carbon (TOC) and total organic halides (TOX) were determined using methods 9060 and 9020, respectively (USEPA 1982).

The radionuclide concentrations were determined using the same detectors as those described for the radionuclide analyses of the mixed fill/sediment. Aliquots of groundwater were taken to dryness on planchets and counted for gross alpha and gross beta activity. The activities of specific alpha emitters were determined following aqueous to nonaqueous separation into phenoltrifloroacetone, plating, and counting using high-resolution alpha-spectrometers. Tritium was determined in groundwater using established liquid-scintillation counting procedures. Strontium-90 in groundwater was separated from the other cations by precipitation as the oxalate salt and then counted on a beta proportional counting system.

6.8 RESULTS AND DISCUSSION OF CHEMICAL ANALYSES OF GROUNDWATER

Groundwater concentrations measured in the four monitoring wells in March and May are presented in Tables 5A and 6A of Appendix A. The constituents presented in Table 5A are those regulated by RCRA (principally those listed in the NIPDWS) as well as those constituents that have been determined to be parameters establishing groundwater quality (chloride, iron, manganese, phenols, sodium, and sulfate) and those that USEPA has determined to be indicators of groundwater contamination (pH, specific conductance, total organic carbon, and total organic halogens). Also included in Table 5A are the concentrations of PCBs, the beta-emitting radionuclides tritium and

^{90}Sr, and the gamma-emitter ^{137}Cs. Listed in Table 6A are the concentrations of elements determined in groundwater samples by ICP spectroscopy.

Table 7 is a summary of measured concentrations of constituents of all analyses from all downgradient wells listed in Table 5A, Appendix A. As can be seen in Tables 7 and 5A, the maximum permitted level for beta-emitting radionuclides is presented as a dose rate of 4 mR per year. However, the gross beta concentrations in Tables 7 and 5A are presented in the commonly accepted manner as activity units (Bq/L). EPA specifies that the dose rate for drinking water be calculated as the total body or organ dose that a person would receive by drinking one liter of the water, daily, for one year (USEPA 1976). According to EPA (USEPA 1976), the activity in drinking water of the beta emitters tritium and ^{90}Sr that results in a dose rate of 4 mR/year are 20,000 pCi/L (740 Bq/L) and 8 pCi/L (0.3 Bq/L), respectively.

Major contaminants in groundwater at the HRE impoundment appear to be radionuclides (e.g., gross alpha and gross beta concentrations exceed NIPDWS concentrations in upgradient as well as downgradient wells). The concentration of gross alpha in the groundwater is rather surprising in light of the quite small levels of transuranics (concentrations generally less than 0.1 Bq/g) in the mixed fill/sediment (see Table 4A, Appendix A). The concentration of gross alpha in groundwater samples appears to vary considerably in wells 3 and 4 between the first and second sampling dates. For example, concentrations in the wells in the June samplings were 10 to 100 times lower than the first sampling dates in either late February or early

Table 7. Concentration of selected groundwater parameters from downgradient wells at the HRE pond summary across all sampling dates

Constituent	Unit	Maximum allowable concentration	Measured concentration				
			Mean	N	Min	Max	%CV
Ag	mg/L	0.05	0.0001	6	0.0001	0.0001	0.0
As	mg/L	0.05	0.0034	6	0.0001	0.0160	187.3
Ba	mg/L	1.0	0.9853	6	0.1050	2.7000	100.5
Cd	mg/L	0.01	0.0012	6	0.0001	0.0035	142.4
Chloride	mg/L	not def	6.3333	6	4.0000	13.0000	53.5
Coliform	Co/100mL	1/100mL	6.3334	6	0.0001	30.0000	186.7
Cr	mg/L	0.05	0.0134	6	0.0001	0.0591	177.7
Endrin	mg/L	0.0002	0.0002	6	0.0001	0.0008	131.9
F	mg/L	1.4-2.4	0.0001	6	0.0001	0.0001	0.0
Fe	mg/L	not def	32.3367	6	2.8800	83.0000	94.4
Gross-A	Bq/L	0.556	6.1333	6	0.1000	24.0000	149.2
Gross-B	Bq/L	4mR/y	467.9333	6	3.6000	950.0000	93.7
Hg	mg/L	0.002	0.0001	6	0.0001	0.0001	0.0
Lindane	mg/L	0.004	0.0001	3	0.0001	0.0001	0.0
Methoxychlor	mg/L	0.1	0.0011	6	0.0001	0.0032	134.5
Mn	mg/L	not def	6.4698	6	0.1800	22.0000	126.9
Nitrate-N	mg/L	10.0	1.1667	6	0.0001	5.0000	174.9
Na	mg/L	not def	13.3500	3	5.6500	21.7000	60.3
Pb	mg/L	0.05	0.0259	6	0.0001	0.0900	136.1
PCB	mg/L	not def	0.0001	3	0.0001	0.0001	23.2
pH	mg/L	not def	6.6733	15	6.4000	6.9000	1.7
Phenol	mg/L	not def	0.0004	6	0.0001	0.0020	186.2
^{226}RA	Bq/L	0.19	0.0634	6	0.0001	0.3300	208.4
Se	mg/L	0.01	0.0001	6	0.0001	0.0001	0.0
Sulfate	mg/L	not def	48.0000	6	34.0000	75.0000	31.1
Sp.Cond.	µS/cm	not def	555.2000	15	272.0000	725.0000	32.6
Toc	mg/L	not def	6.0260	15	2.0800	8.4000	31.2
Tox	mg/L	not def	0.1732	6	0.0060	0.4100	107.6
Toxaphene	mg/L	not def	0.0014	6	0.0001	0.0052	152.1
Tritium	Bq/L	not def	203.5000	2	37.0000	370.0000	115.7
^{137}Cs	Bq/L	not def	0.4824	6	0.0001	2.0799	165.2
2,4-D	mg/L	0.1	0.0001	6	0.0001	0.0001	0.0
2,4,5-TP	mg/L	0.01	0.0001	6	0.0001	0.0001	0.0
^{90}Sr	Bq/L	not def	180.6267	3	0.5800	540.0000	172.3

March (Table 5A, Appendix A). Further sampling should clarify the extent of variation.

Two wells, numbers 3 and 4 sampled in late February and early March, showed concentrations of barium in groundwater that were in excess of the NIPDWS maximum level (Table 5A, Appendix A). The source of barium in the groundwater is not clear. The concentration of barium in the EP extract of the mixed fill/sediment was < 1 mg/L (approximately 100 times lower than the maximum allowable EP concentration), and the total barium concentration of the material was observed to be between 300 and 400 mg/kg (see Table 2A)-not greatly different than many soils. For example, soil solutions from the same soil type as that used as the fill contain concentrations of barium approaching 1 mg/L. Again, further sampling will be required to determine a definitive trend. One groundwater sample (taken from well 4 in June of 1985) showed a chromium concentration of 0.059 mg/L which is equivalent to the maximum allowable NIPDWS concentration (0.05 mg/L). However, all other groundwater samples were near detection levels (0.0001 mg/L), indicating that the elevated chromium measurement is likely a statistical outlier or a faulty measurement. Lead measured in the groundwater also exceeded the maximum allowable NIPDWS concentration on two sampling dates: one was in an upgradient well (sampled in late February), and the other in well 3, also sampled in late February. Further sampling will allow statistical comparisons between upgradient and downgradient wells to confirm lead contamination of groundwater. The mean lead concentration in downgradient wells sampled to date is 0.0259 mg/L (see Table 7), well below the NIPDWS maximum allowable limit (0.05 mg/L).

Counts of coliform bacteria in groundwater upgradient as well as downgradient were in excess of the NIPDWS. These counts may result from wildlife habitat such as waterfowl and terrestrial animals known to be in the area. These also may represent sampling and analytical variations. Additional monitoring will indicate a trend over time. The concentrations of total organic carbon (TOC) and total organic halides (TOX) in groundwater samples appear to be relatively constant regardless of the monitoring well sampled, upgradient or downgradient the HRE impoundment. Detectable concentrations of PCBs were measured in the downgradient monitoring wells (0.0001 mg/L) whereas in the single sampling date (May, 21, 1985) in the upgradient well, its concentration could not be detected.

Concentrations of silver, arsenic, cadmium, mercury, and selenium in groundwater sampled to date are all well below the maximum NIPDS limits. Also, evidence of potential contamination by barium, chromium, and lead will be determined through continued sampling. To date, however, it appears that the groundwater contamination is limited to radionuclides, principally ^{90}Sr, ^{137}Cs, and tritium.

7. IMPOUNDMENT CLOSURE

7.1 CURRENT CONCEPT FOR POND-CLOSURE

The current technical plan for closure of the impoundment is by entombment and is summarized by Myrick (1984) as follows:

> The first phase of pond stabilization would involve removal of 55-gal drums that are buried adjacent to the pond. These drums would be excavated and sent to the ORNL burial grounds as LLW. Formation of the grout curtain surrounding the pond would then follow, utilizing high pressure injection pumps. Grout sheets would then be formed above and below the contaminated pond sediments in order to isolate the contaminated materials from groundwater flows. Once the pond is stabilized, the asphalt concrete cap would be resurfaced, sealed, and permanently marked.

7.2 CHARACTERIZATION RESULTS TO BE CONSIDERED

The groundwater table is approximately 10 ft (3 m) above the bottom of the soil-filled impoundment. This is probably several feet higher than when the pond was in operation and is higher than generally estimated when remedial techniques were considered for decommissioning the impoundment (W. R. Reed, pers. commun.). In light of the high water table, the current technical plan for decommissioning needs additional consideration. It is questionable whether the grouting as indicated by Myrick (1984) would assure isolation of the mixed soil and sediment waste from the groundwater.

The sampling borings (SP-1 through SP-2, Appendix B) conducted in the soil-filled impoundment indicate that the sediment is mixed with the soil and does not cover just the bottom of the impoundment. Considering the method of filling (the impoundment), the ratio of the waste to soil mixture is expected to be very heterogeneous.

8. ADDITIONAL DATA NEEDS

8.1 GROUNDWATER SAMPLING

Monitoring wells at the HRE impoundment will be sampled at least twice more so that four quarters of data on RCRA-regulated constituents (see Table 6) will be available. For impoundments active after November 19, 1980, RCRA regulations require that at the end of the first year of sampling, statistical analyses be performed on the data from the four quarters to determine whether the groundwater is polluted by the impoundment. Pollution is assumed if the analysis (Cochran's Approximation to the Behrens-Fisher Student's t test or an approved similar test) indicates a significant increase (decrease in the case of pH) in the water quality parameters listed in Table 6 between the upgradient and downgradient wells. This procedure for determining pollution will be considered for the HRE impoundment after four quarters of sampling and analyses have been completed.

8.2 POTENTIAL SUBSURFACE EXPLORATION

If results of continued sampling confirm that the HRE impoundment has significantly contaminated the groundwater, then additional exploration or monitoring wells will be considered in the appropriate areas to assist in determining the extent and contaminate concentrations of the plume.

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APPENDIX A

ANALYTICAL TABLES:
1A through 6A

Notes for all Tables:

1. The "-" (minus) symbol is used to represent the detection level
2. Detection limit for the same constituent varied among the analyses due to sample dilution and matrix effects.

TABLE 1A. CONCENTRATIONS OF RCRA NONREGULATED CONSTITUENTS
IN EP EXTRACTS FROM HRE IMPOUNDMENT FILL/SEDIMENT

CONSTITUENT	UNIT	LOCATION	SAMPLE DATE	MEASURED CONCENTRATION MEAN
AL	MG/L	COMPOSITE	03/06/85	-0.0001
B	MG/L	COMPOSITE	03/06/85	-0.0001
BE	MG/L	COMPOSITE	03/06/85	0.0048
CA	MG/L	COMPOSITE	03/06/85	540.0000
CD	MG/L	COMPOSITE	03/06/85	0.0470
CU	MG/L	COMPOSITE	03/06/85	-0.0001
FE	MG/L	COMPOSITE	03/06/85	-0.0001
GA	MG/L	COMPOSITE	03/06/85	-0.0001
HF	MG/L	COMPOSITE	03/06/85	0.2000
K	MG/L	COMPOSITE	03/06/85	4.2000
LI	MG/L	COMPOSITE	03/06/85	-0.0001
MG	MG/L	COMPOSITE	03/06/85	44.0000
MN	MG/L	COMPOSITE	03/06/85	15.0000
MO	MG/L	COMPOSITE	03/06/85	-0.0001
NA	MG/L	COMPOSITE	03/06/85	2.0000
NI	MG/L	COMPOSITE	03/06/85	-0.0001
P	MG/L	COMPOSITE	03/06/85	-0.0001
SB	MG/L	COMPOSITE	03/06/85	-0.0001
SI	MG/L	COMPOSITE	03/06/85	-0.0001
SR	MG/L	COMPOSITE	03/06/85	0.3000
TI	MG/L	COMPOSITE	03/06/85	0.0230
V	MG/L	COMPOSITE	03/06/85	-0.0001
ZN	MG/L	COMPOSITE	03/06/85	0.1400
CONSTITUENT	UNIT	LOCATION	SAMPLE DATE	
ZR	MG/L	COMPOSITE	03/06/85	-0.0001

TABLE 2A. TOTAL ANALYSIS OF HRE IMPOUNDMENT FILL/SEDIMENT

				MEASURED CONCENTRATION
				MEAN
CONSTITUENT	UNIT	LOCATION	SAMPLE DATE	
AG	MG/KG	SP-1	03/01/85	-0.0001
		SP-2	03/04/85	-0.0001
		SP-3	03/05/85	-0.0001
		SP-4	03/06/85	-0.0001
AL	MG/KG	SP-1	03/01/85	87000.0000
		SP-2	03/04/85	78000.0000
		SP-3	03/05/85	85000.0000
		SP-4	03/06/85	84000.0000
AS	MG/KG	SP-1	03/01/85	-0.0001
		SP-2	03/04/85	-0.0001
		SP-3	03/05/85	-0.0001
		SP-4	03/06/85	-0.0001
BA	MG/KG	SP-1	03/01/85	310.0000
		SP-2	03/04/85	310.0000
		SP-3	03/05/85	420.0000
		SP-4	03/06/85	450.0000
BE	MG/KG	SP-1	03/01/85	2.3000
		SP-3	03/05/85	2.4000
		SP-4	03/06/85	2.4000
CA	MG/KG	SP-1	03/01/85	10000.0000
		SP-2	03/04/85	3600.0000
		SP-3	03/05/85	6600.0000
		SP-4	03/06/85	8700.0000

(CONTINUED)

TABLE 2A. TOTAL ANALYSIS OF HRE IMPOUNDMENT FILL/SEDIMENT

CONSTITUENT	UNIT	LOCATION	SAMPLE DATE	MEASURED CONCENTRATION MEAN
CD	MG/KG	SP-1	03/01/85	3.3000
		SP-2	03/04/85	3.1000
		SP-3	03/05/85	-0.0001
		SP-4	03/06/85	-0.0001
CO	MG/KG	SP-1	03/01/85	23.0000
		SP-2	03/04/85	24.0000
		SP-3	03/05/85	18.0000
		SP-4	03/06/85	19.0000
CR	MG/KG	SP-1	03/01/85	68.5000
		SP-2	03/04/85	91.0000
		SP-3	03/05/85	92.0000
		SP-4	03/06/85	99.0000
CU	MG/KG	SP-2	03/04/85	27.0000
		SP-3	03/05/85	21.0000
		SP-4	03/06/85	36.0000
GA	MG/KG	SP-1	03/01/85	-0.0001
		SP-2	03/04/85	-0.0001
		SP-3	03/05/85	-0.0001
		SP-4	03/06/85	-0.0001
HF	MG/KG	SP-1	03/01/85	13.0000
		SP-2	03/04/85	-0.0001
		SP-3	03/05/85	11.0000
		SP-4	03/06/85	12.0000

(CONTINUED)

TABLE 2A. TOTAL ANALYSIS OF FRE IMPCUNDMENT FILL/SEDIMENT

CONSTITUENT	UNIT	LOCATION	SAMPLE DATE	MEASURED CONCENTRATION MEAN
K	MG/KG	SP-1	03/01/85	26000.0000
		SP-2	03/04/85	21000.0000
		SP-3	03/05/85	25000.0000
		SP-4	03/06/85	26000.0000
LI	MG/KG	SP-1	03/01/85	94.0000
		SP-2	03/04/85	68.0000
		SP-3	03/05/85	84.0000
		SP-4	03/06/85	88.0000
MG	MG/KG	SP-1	03/01/85	8100.0000
		SP-2	03/04/85	6000.0000
		SP-3	03/05/85	7400.0000
		SP-4	03/06/85	8100.0000
MN	MG/KG	SP-1	03/01/85	510.0000
		SP-2	03/04/85	340.0000
		SP-3	03/05/85	540.0000
		SP-4	03/06/85	550.0000
MO	MG/KG	SP-1	03/01/85	-0.0001
		SP-2	03/04/85	-0.0001
		SP-3	03/05/85	-0.0001
		SP-4	03/06/85	-0.0001
NA	MG/KG	SP-1	03/01/85	4200.0000
		SP-2	03/04/85	2600.0000
		SP-3	03/05/85	3400.0000

(CONTINUED)

TABLE 2A. TOTAL ANALYSIS OF FRE IMPOUNDMENT FILL/SEDIMENT

CONSTITUENT	UNIT	LOCATION	SAMPLE DATE	MEASURED CONCENTRATION MEAN
NA	MG/KG	SP-4	03/06/85	4600.0000
NI	MG/KG	SP-1	03/01/85	43.0000
		SP-2	03/04/85	37.0000
		SP-3	03/05/85	38.0000
		SP-4	03/06/85	43.0000
P	MG/KG	SP-1	03/01/85	280.0000
		SP-2	03/04/85	290.0000
		SP-3	03/05/85	250.0000
		SP-4	03/06/85	450.0000
PB	MG/KG	SP-1	03/01/85	-0.0001
		SP-2	03/04/85	-0.0001
		SP-3	03/05/85	-0.0001
		SP-4	03/06/85	-0.0001
PCB	MG/KG	SP-1	03/06/85	0.3300
		SP-2	03/04/85	0.3900
		SP-3	03/05/85	0.0120
		SP-4	03/06/85	0.0190
SB	MG/KG	SP-1	03/01/85	-0.0001
		SP-2	03/04/85	-0.0001
		SP-3	03/05/85	-0.0001
		SP-4	03/06/85	-0.0001
SE	MG/KG	SP-1	03/01/85	-0.0001
		SP-2	03/04/85	-0.0001

(CONTINUED)

TABLE 2A. TOTAL ANALYSIS OF PRE IMPOUNDMENT FILL/SEDIMENT

CONSTITUENT	UNIT	LOCATION	SAMPLE DATE	MEASURED CONCENTRATION MEAN
SE	MG/KG	SP-3	03/05/85	-0.0001
		SP-4	03/06/85	-0.0001
SR	MG/KG	SP-1	03/01/85	77.0000
		SP-2	03/04/85	66.0000
		SP-3	03/05/85	71.0000
		SP-4	03/06/85	76.0000
TI	MG/KG	SP-1	03/01/85	4500.0000
		SP-2	03/04/85	4500.0000
		SP-3	03/05/85	4300.0000
		SP-4	03/06/85	4400.0000
V	MG/KG	SP-1	03/01/85	94.0000
		SP-2	03/04/85	77.0000
		SP-3	03/05/85	86.0000
		SP-4	03/06/85	88.0000
ZN	MG/KG	SP-1	03/01/85	84.0000
		SP-2	03/04/85	92.0000
		SP-3	03/05/85	74.0000
		SP-4	03/06/85	91.0000
ZR	MG/KG	SP-1	03/01/85	150.0000
		SP-2	03/04/85	130.0000
		SP-3	03/05/85	120.0000
		SP-4	03/06/85	120.0000

TABLE 3A. INVENTORY OF CONSTITUENTS IN HRE IMPOUNDMENT FILL/SEDIMENT

CONSTITUENT	UNIT	TOTAL INVENTORY MEAN
AG	KG	0.00
AL	KG	166231.80
AS	KG	0.00
BA	KG	741.57
BE	KG	4.71
CA	KG	14383.53
CD	KG	3.19
CO	KG	41.81
CR	KG	166.83
CU	KG	55.74
GA	KG	0.00
HF	KG	17.92
K	KG	48774.60
LI	KG	166.23
MG	KG	14731.92
MN	KG	965.54
MO	KG	0.00
NA	KG	7365.96
NI	KG	80.13
P	KG	632.08
PB	KG	0.00
PCB	KG	0.37
SB	KG	0.00
SE	KG	0.00

(CONTINUED)

TABLE 3A. INVENTORY OF CONSTITUENTS IN HRE IMPOUNDMENT FILL/SEDIMENT

CONSTITUENT	UNIT	TOTAL INVENTORY MEAN
SR	KG	144.33
TI	KG	8809.29
V	KG	171.71
ZN	KG	169.72
ZR	KG	258.80

TABLE 4A. RADIONULCIDES MEASURED IN HRE IMPOUNDMENT FILL/SEDIMENT

CONSTITUENT	UNIT	LOCATION	SAMPLE DATE	MEASURED CONCENTRATION MEAN
GROSS-A	BQ/G	SP-1B	03/01/85	-0.0001
		SP-1BH	03/01/85	-0.0001
		SP-2	03/04/85	-0.0001
		SP-2H	03/04/85	-0.0001
		SP-3	03/05/85	-0.0001
		SP-4	03/06/85	-0.0001
GROSS-B	BQ/G	SP-1B	03/01/85	940.0000
		SP-1BH	03/01/85	14000.0000
		SP-2	03/04/85	540.0000
		SP-2H	03/04/85	128000.0000
		SP-3	03/05/85	48.0000
		SP-4	03/06/85	260.0000
137CS	BQ/G	SP-1B	03/01/85	76.0000
		SP-1BH	03/01/85	1990.0000
		SP-2	03/04/85	58.0000
		SP-2H	03/04/85	1640.0000
		SP-3	03/05/85	8.9000
		SP-4	03/06/85	56.0000
234U	BQ/G	SP-1B	03/01/85	0.0850
		SP-2	03/04/85	0.0550
		SP-3	03/05/85	0.0400
		SP-4	03/06/85	0.0680
235U	BQ/G	SP-1B	03/01/85	0.0150

(CONTINUED)

TABLE 4A. RADIONULCIDES MEASURED IN HRE IMPOUNDMENT FILL/SEDIMENT

CONSTITUENT	UNIT	LOCATION	SAMPLE DATE	MEASURED CONCENTRATION MEAN
235U	BQ/G	SP-2	03/04/85	0.0040
		SP-3	03/05/85	0.0050
		SP-4	03/06/85	0.0100
238PU	BQ/G	SP-2	03/04/85	0.0001
		SP-3	03/05/85	-0.0001
		SP-4	03/06/85	0.0003
238U	BQ/G	SP-1B	03/01/85	0.0570
		SP-2	03/04/85	0.0320
		SP-3	03/05/85	0.0260
		SP-4	03/06/85	0.0440
239PU	BQ/G	SP-1B	03/01/85	-0.0001
		SP-2	03/04/85	0.0051
		SP-3	03/05/85	0.0017
		SP-4	03/06/85	0.0038
241AM	BQ/G	SP-1B	03/01/85	0.0005
		SP-2	03/04/85	0.0006
		SP-3	03/05/85	-0.0001
		SP-4	03/06/85	0.0008
60CO	BQ/G	SP-1B	03/01/85	0.0234
		SP-2	03/04/85	0.0139
		SP-3	03/05/85	-0.0001
		SP-4	03/06/85	0.0570
90SR	BQ/G	SP-1B	03/01/85	300.0000

(CONTINUED)

TABLE 4A. RADIONULCIDES MEASURED IN HRE IMPOUNDMENT FILL/SEDIMENT

				MEASURED CONCENTRATION
				MEAN
CONSTITUENT	UNIT	LOCATION	SAMPLE DATE	
90SR	BQ/G	SP-1BH	03/01/85	14400.0000
		SP-2	03/04/85	20.0000
		SP-2H	03/04/85	5460.0000
		SP-3	03/05/85	100.0000
		SP-4	03/06/85	100.0000

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
AG	MG/L	0.05	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001
AS	MG/L	0.05	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	0.0160
				05/22/85	-0.0001
			4	03/04/85	0.0040
				05/22/85	-0.0001
BA	MG/L	1.0	1	02/28/85	0.0830
				05/21/85	0.1200
			2	02/28/85	0.9500
				05/22/85	0.1630
			3	02/28/85	1.5000
				05/22/85	0.1050

(CONTINUED)

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
BA	MG/L	1.0	4	03/04/85	2.7000
				05/22/85	0.4940
CD	MG/L	0.01	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	0.0035
			4	03/04/85	-0.0001
				05/22/85	0.0035
CHLORIDE	MG/L	NOT DEF	1	02/28/85	12.0000
				05/21/85	7.0000
			2	02/28/85	13.0000
				05/22/85	5.0000
			3	02/28/85	6.0000
				05/22/85	4.0000
			4	03/04/85	6.0000
				05/22/85	4.0000
COLIFORM	CC/100ML	1/100ML	1	02/28/85	8.0000
				05/21/85	4.0000
			2	02/28/85	30.0000
				05/22/85	-0.0001

(CONTINUED)

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATI-ON	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRAT-ION MEAN
COLIFORM	CO/100ML	1/100ML	3	02/28/85	-0.0001
				05/22/85	2.0000
			4	03/04/85	-0.0001
				05/22/85	6.0000
CR	MG/L	0.05	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	0.0212
			4	03/04/85	-0.0001
				05/22/85	0.0591
ENDRIN	MG/L	0.0002	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	0.0008
				05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001
F	MG/L	1.4-2.4	1	02/28/85	-0.0001
				05/21/85	-0.0001

(CONTINUED)

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
F	MG/L	1.4-2.4	2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001
FE	MG/L	NOT DEF	1	02/28/85	0.4800
				05/21/85	4.5900
			2	02/28/85	24.0000
				05/22/85	2.8800
			3	02/28/85	83.0000
				05/22/85	4.1400
			4	03/04/85	51.0000
				05/22/85	29.0000
GROSS-A	BQ/L	0.556	1	02/28/85	1.0000
				05/21/85	0.9000
			2	02/28/85	6.0000
				05/22/85	5.6000
			3	02/28/85	1.0000
				05/22/85	0.1000
			4	03/04/85	24.0000
				05/22/85	0.1000

(CONTINUED)

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
GROSS-B	PC/L	4MREM/YR	1	02/28/85	10.0000
				05/21/85	3.5000
			2	02/28/85	720.0000
				05/22/85	950.0000
			3	02/28/85	24.0000
				05/22/85	3.6000
			4	03/04/85	900.0000
				05/22/85	210.0000
HG	MG/L	0.002	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001
LINDANE	MG/L	0.004	1	05/21/85	-0.0001
			2	05/22/85	-0.0001
			3	05/22/85	-0.0001
			4	05/22/85	-0.0001
METHOXYCHLOR	MG/L	0.1	1	02/28/85	0.0008
				05/21/85	-0.0001

(CONTINUED)

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
METHOXYCHLOR	MG/L	0.1	2	02/28/85	0.0028
				05/22/85	-0.0001
			3	02/28/85	0.0003
				05/22/85	-0.0001
			4	03/04/85	0.0032
				05/22/85	-0.0001
MN	MG/L	NOT DEF	1	02/28/85	0.1500
				05/21/85	0.1980
			2	02/28/85	6.3000
				05/22/85	0.7890
			3	02/28/85	7.8000
				05/22/85	0.1800
			4	03/04/85	22.0000
				05/22/85	1.7500

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
NA	MG/L	NOT DEF	1	05/21/85	6.8000
			2	05/22/85	12.7000
			3	05/22/85	21.7000
			4	05/22/85	5.6500
PB	MG/L	0.05	1	02/28/85	0.0700
				05/21/85	-0.0001
			2	02/28/85	0.0300
				05/22/85	-0.0001
			3	02/28/85	0.0900
				05/22/85	-0.0001
			4	03/04/85	0.0350
				05/22/85	-0.0001
PCB	MG/L	NOT DEF	1	05/21/85	-0.0001
			2	05/22/85	0.0001
			3	05/22/85	0.0001
			4	05/22/85	0.0001
PH	PH	NOT DEF	1	02/28/85	6.8000
				05/21/85	6.9000
			2	02/28/85	6.7000
				05/21/85	6.7250
			3	02/28/85	6.9000
				05/22/85	6.6000

(CONTINUED)

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
PH	PH	NOT DEF	4	03/04/85	6.7000
				05/22/85	6.6250
PHENOL	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	-0.0001
			4	03/04/85	0.0020
				05/22/85	-0.0001
226RA	BQ/L	0.19	1	02/28/85	0.0100
				05/21/85	-0.0001
			2	02/28/85	0.3300
				05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	-0.0001
			4	03/04/85	0.0500
				05/22/85	-0.0001
SE	MG/L	0.01	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001

(CONTINUED)

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
SE	MG/L	0.01	3	02/28/85	-0.0001
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001
SULFATE	MG/L	NOT DEF	1	02/28/85	54.0000
				05/21/85	42.0000
			2	02/28/85	75.0000
				05/22/85	55.0000
			3	02/28/85	39.0000
				05/22/85	43.0000
			4	03/04/85	42.0000
				05/22/85	34.0000
SP.COND.	UMHOS/CC	NOT DEF	1	02/28/85	636.0000
				05/21/85	572.2500
			2	02/28/85	721.0000
				05/21/85	715.5000
			3	02/28/85	725.0000
				05/22/85	284.7500
			4	03/04/85	632.0000
				05/22/85	562.2500
TOC	MG/L	NOT DEF	1	02/28/85	2.8500
				05/21/85	6.4750

(CONTINUED)

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
TOC	MG/L	NOT DEF	2	02/28/85	2.2900
				05/22/85	5.8750
			3	02/28/85	2.0800
				05/22/85	8.2250
			4	03/04/85	5.3200
				05/22/85	6.0750
TOX	MG/L	NOT DEF	1	02/28/85	0.5400
				05/21/85	0.0140
			2	02/28/85	0.4100
				05/22/85	0.0150
			3	02/28/85	0.3600
				05/22/85	0.0130
			4	03/04/85	0.2350
				05/22/85	0.0060
TOXAPHENE	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	0.0030
				05/22/85	-0.0001
			3	02/28/85	0.0052
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001

(CONTINUED)

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
TRITIUM	PCI/L	NOT DEF	1	05/21/85	[illegible]
			2	05/22/85	[illegible]
			3	05/22/85	[illegible]
			4	05/22/85	[illegible]
137CS	PCI/L	NOT DEF	1	02/28/85	[illegible]
				05/22/85	[illegible]
			2	02/28/85	[illegible]
				05/22/85	[illegible]
			3	02/28/85	[illegible]
				05/22/85	[illegible]
			4	03/04/85	[illegible]
				05/22/85	[illegible]
2,4-D	MG/L	0.1	1	02/28/85	[illegible]
				05/21/85	[illegible]
			2	02/28/85	[illegible]
				05/22/85	[illegible]
			3	02/28/85	[illegible]
				05/22/85	[illegible]
			4	03/04/85	[illegible]
				05/22/85	[illegible]
2,4,5-TP	MG/L	0.01	1	02/28/85	[illegible]
				05/21/85	[illegible]

(CONTINUED)

TABLE 5A. INDEX OF GROUNDWATER QUALITY FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
2,4,5-TP	MG/L	0.01	2	05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001
90SR	BQ/L	NOT DEF	1	05/21/85	0.2600
			2	05/22/85	540.0000
			3	05/22/85	1.3000
			4	05/22/85	0.5800

TABLE 6A. SUPPLEMENTARY GROUNDWATER QUALITY MEASUREMENTS
FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
AL	MG/L	NOT DEF	1	02/28/85	0.3000
				05/21/85	2.8100
			2	02/28/85	8.6000
				05/22/85	1.5200
			3	02/28/85	28.0000
				05/22/85	1.8200
			4	03/04/85	22.0000
				05/22/85	17.8000
B	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	0.1900
				05/22/85	-0.0001
			3	02/28/85	0.1000
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001
BE	MG/L	NOT DEF	1	02/28/85	0.0020
				05/21/85	-0.0001
			2	02/28/85	0.0064
				05/22/85	-0.0001
			3	02/28/85	0.0130

(CONTINUED)

TABLE 6A. SUPPLEMENTARY GROUNDWATER QUALITY MEASUREMENTS
FOR THE HRE SITE

					MEASURED CONCENTRATION
					MEAN
CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	
BE	MG/L	NOT DEF	3	05/22/85	-0.0001
			4	03/04/85	0.0260
				05/22/85	0.0022
CA	MG/L	NOT DEF	1	02/28/85	76.0000
				05/21/85	95.1000
			2	02/28/85	400.0000
				05/22/85	130.0000
			3	02/28/85	470.0000
				05/22/85	130.0000
			4	03/04/85	1400.0000
				05/22/85	188.0000
CR	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	0.0250
				05/22/85	-0.0001
			3	02/28/85	0.0690
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	0.0255
CU	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001

(CONTINUED)

TABLE 6A. SUPPLEMENTARY GROUNDWATER QUALITY MEASUREMENTS
FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
CU	MG/L	NOT DEF	2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	0.0320
GA	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001
HF	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	0.1600
				05/22/85	-0.0001
			3	02/28/85	0.2200
				05/22/85	-0.0001
			4	05/22/85	-0.0001

(CONTINUED)

TABLE 6A. SUPPLEMENTARY GROUNDWATER QUALITY MEASUREMENTS
FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
K	MG/L	NOT DEF	1	02/28/85	7.0000
				05/21/85	1.4000
			2	02/28/85	13.0000
				05/22/85	4.0000
			3	02/28/85	21.0000
				05/22/85	3.9000
			4	03/04/85	9.2000
				05/22/85	3.8000
LI	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	0.3200
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001
MG	MG/L	NOT DEF	1	02/28/85	13.0000
				05/21/85	17.2000
			2	02/28/85	28.0000
				05/22/85	20.0000
			3	02/28/85	40.0000

(CONTINUED)

TABLE 6A. SUPPLEMENTARY GROUNDWATER QUALITY MEASUREMENTS
FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
MG	MG/L	NOT DEF	3	05/22/85	20.2000
			4	03/04/85	61.0000
				05/22/85	27.1000
MO	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	0.0220
				05/22/85	-0.0001
			3	02/28/85	0.0290
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001
NI	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	0.0680
				05/22/85	-0.0001
			4	03/03/85	-0.0001
				05/22/85	-0.0001
P	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001

(CONTINUED)

TABLE 6A. SUPPLEMENTARY GROUNDWATER QUALITY MEASUREMENTS FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
P	MG/L	NOT DEF	2	02/28/85	1.2000
				05/22/85	-0.0001
			3	02/28/85	5.0000
				05/22/85	-0.0001
			4	03/04/85	2.1000
				05/22/85	0.3230
SR	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	-0.0001
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001
SI	MG/L	NOT DEF	1	02/28/85	3.2000
				05/21/85	7.8600
			2	02/28/85	12.0000
				05/22/85	11.7000
			3	02/28/85	29.0000
				05/22/85	14.4000
			4	03/04/85	-0.0001

(CONTINUED)

TABLE 6A. SUPPLEMENTARY GROUNDWATER QUALITY MEASUREMENTS FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
SI	MG/L	NOT DEF	4	05/22/85	25.2000
SR	MG/L	NOT DEF	1	02/28/85	0.1000
				05/21/85	0.0858
			2	02/28/85	0.3000
				05/22/85	0.1480
			3	02/28/85	0.6500
				05/22/85	0.3450
			4	03/04/85	1.1000
				05/22/85	0.1780
TI	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	0.0329
			2	02/28/85	0.0460
				05/22/85	0.0215
			3	02/28/85	0.1200
				05/22/85	0.0229
			4	03/04/85	-0.0001
				05/22/85	0.0514
V	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	0.0308
			2	02/28/85	0.0420
				05/22/85	0.0326

(CONTINUED)

TABLE 6A. SUPPLEMENTARY GROUNDWATER QUALITY MEASUREMENTS
FOR THE HRE SITE

CONSTITUENT	UNIT	MAXIMUM ALLOWABLE CONCENTRATION	WELL NUMBER	SAMPLE DATE	MEASURED CONCENTRATION MEAN
V	MG/L	NOT DEF	3	02/28/85	0.0840
				05/22/85	0.0353
			4	03/04/85	-0.0001
				05/22/85	0.0668
ZN	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	0.0520
				05/22/85	-0.0001
			3	02/28/85	0.1300
				05/22/85	-0.0001
			4	03/04/85	0.1400
				05/22/85	0.0831
ZR	MG/L	NOT DEF	1	02/28/85	-0.0001
				05/21/85	-0.0001
			2	02/28/85	-0.0001
				05/22/85	-0.0001
			3	02/28/85	0.1300
				05/22/85	-0.0001
			4	03/04/85	-0.0001
				05/22/85	-0.0001

APPENDIX B

DRILLING LOGS OF BORINGS:
SP-1 through SP-4,
and
MW-1 through MW-4

Hole No. SP-1

DRILLING LOG	DIVISION: Environmental Sciences	INSTALLATION: Oak Ridge National Laboratory	SHEET 1 OF 1 SHEETS

1. PROJECT: SFMP-HRE Soil-Filled Pond	10. SIZE AND TYPE OF BIT: 1 1/2" split spoon
2. LOCATION (Coordinates or Station): (Within 3.0' of SP-1B)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
3. DRILLING AGENCY: Plant & Engineering Division	12. MANUFACTURER'S DESIGNATION OF DRILL: Mobile B-33
4. HOLE NO. (As shown on drawing title and file number): SP-1	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED: 8 Jars; UNDISTURBED:
5. NAME OF DRILLER: P. E. Moore	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
7. THICKNESS OF OVERBURDEN: 15.6'	16. DATE HOLE: STARTED 1/14/85; COMPLETED 1/15/85
8. DEPTH DRILLED INTO ROCK: 0.1'	17. ELEVATION TOP OF HOLE: 818' approximately
9. TOTAL DEPTH OF HOLE: 15.7'	18. TOTAL CORE RECOVERY FOR BORING %
	19. SIGNATURE OF INSPECTOR: R. G. Stansfield

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
818.0			Asphalt Concrete 0.2' Crushed stone & clay 1.0'	Auger	No Sample 1.1'	Boring and sampling conducted by driving 1 1/2" x 24" split-tube sampler.
817.0	1–2		CLAY (CL) FILL Medium, moist Red-yellowish brown with mudstone fragments	90%	Jar 1 3.1'	
	3–4			70%	Jar 2 5.0'	Samples and drill cuttings checked with G/M meter.
	5				5.1'	Jar 3 (Sample measured 10 mrad)
	5–7		CLAY (CL) FILL Medium to soft, wet, gray with some brown mottling	40%	Jar 4 7.1'	No reading in excess of 2 mrad was measured. Samples Jars 4 through 9.
	7–8			0%	No Sample 8.1'	
	8–9			50%	Jar 5 9.1'	
	9–10			50%	Jar 6 11.1'	Water encountered during drilling at approximately 5' depth. Excess material placed in cans for disposal.
	10–11		Occasional black staining from 10.0' down			
	11–12			80%	Jar 7 12.1'	
	12–14			80%	Jar 8 14.1'	
	14–15			80% 15.0'	Jar 9	Boring filled with sand and capped with concrete on 3/6/85.
	15		15.6'	42%	15.7'	
802.4 802.5	16		SHALE greenish-gray 15.7'			
	17		Bottom of hole split-spoon refusal			

PROJECT | HOLE NO. SP-1

Hole No. SP-1A

DRILLING LOG	DIVISION Environmental Sciences	INSTALLATION Oak Ridge National Laboratory	SHEET 1 OF 1 SHEETS
1. PROJECT SEMP-HRE Soil-Filled Pond		10. SIZE AND TYPE OF BIT 8" Auger to 11.5'	
2. LOCATION (Coordinates or Station) (Within 3' of SP-1B)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY Plant & Equipment Division		12. MANUFACTURER'S DESIGNATION OF DRILL Mobile B-33	
4. HOLE NO. (As shown on drawing title and file number) SP-1A		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 4 Jars; UNDISTURBED	
5. NAME OF DRILLER P. E. Moore		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE X VERTICAL ☐ INCLINED ______ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
		16. DATE HOLE: STARTED 1/15/85; COMPLETED 1/16/85	
7. THICKNESS OF OVERBURDEN 16.1'		17. ELEVATION TOP OF HOLE 818' approximately	
8. DEPTH DRILLED INTO ROCK -		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 16.1'		19. SIGNATURE OF INSPECTOR R. G. Stansfield	

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
818.0			Asphaltic Concrete 0.2'	Auger	No Sample	1 1/2" x 24" split-tube sampler driven through hollow-stem auger in drives as shown. Auger was advanced after each drive to depth of 11.5' when augering was terminated as it was starting to bring up contaminated water.
			Crushed Stoned Clay 1.0'			
817.0	1		CLAY (CL) FILL Medium, moist Red-yellowish brown with mudstone fragments			
	2			50%	Jar 1	
					3.0'	
	3					
	4			25%		Water encountered during drilling at approximate depth of 5'.
	5		At approximately 5', color changes to brown; consistency to medium to soft; and moisture to wet		Jar 2	
	6			10%		Drill cuttings and excess sample were placed in cans for disposal.
	7				7.7'	
	8					Samples and cuttings checked with G/M meter during drilling; no readings in excess of approximately 2 mrad were measured.
	9			10% 9.5'		
	10			13% 11.0'	Jar 3	Boring backfilled with sand and capped with concrete.
	11			10% 12.0'		
	12					
	13			57%	13.4'	
	14			47%	Jar 4	
	15			15.5'		
801.9	16		16.1' Split spoon refusal bottom of hole	0%	16.1'	
	17					

PROJECT | HOLE NO. SP-1A

Hole No. SP-1B

DRILLING LOG	DIVISION Environmental Sciences	INSTALLATION Oak Ridge National Laboratory	SHEET 1 OF 1 SHEETS
1. PROJECT SFMP-HRE Soil-Filled Pond		10. SIZE AND TYPE OF BIT 8" Auger	
2. LOCATION (Coordinates or Station) N18600.49; E31486.19		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY Plant & Equipment Division		12. MANUFACTURER'S DESIGNATION OF DRILL Mobile B-33	
4. HOLE NO. (As shown on drawing title and file number) SP-1B		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 6 Jars; UNDISTURBED	
5. NAME OF DRILLER P. E. Moore		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
		16. DATE HOLE: STARTED 3/1/85; COMPLETED 3/1/85	
7. THICKNESS OF OVERBURDEN 16.7'		17. ELEVATION TOP OF HOLE 818.26'	
8. DEPTH DRILLED INTO ROCK 0.3'		18. TOTAL CORE RECOVERY FOR BORING %	
9. TOTAL DEPTH OF HOLE 17.0'		19. SIGNATURE OF INSPECTOR R. G. Stansfield	

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
818.3			Asphaltic Pavement 0.4'	A		Augered to 5.0' depth and obtained sample Jar #1 from bit.
			Crushed Limestone & Clay 1.0'	U		
817.3	1		CLAY (CL) FILL with occasional shale & limestone fragments up to at least 2 1/2" size	G E R E D		Water encountered during drilling at depth of approximately 5'.
	2					
	3					Installed CME sampler at 5.0' depth with end of sampler protruding 0.3' below auger bit.
	4				5.0' Jar 1 0.5 mR	
	5			5.0'		Drill cuttings and excess sample placed in cans for disposal.
	6		Color is brown to 5.0' depth. Below 5.0', color is borwn with zones and inclusions of gray		Jar 2 20 mR	Samples and drill cuttings checked with G/M meter and measurements recorded in Col. "f" in mR.
	7				7.5'	
	8			50%	Jar 3 5mR	
	9					Boring backfilled with sand and capped with concrete on 3/6/85.
	10			10.0'	10.0'	
	11					
	12			26%	Jar 4 1 mR	
	13					
	14					
	15			15.0'	15.0'	
	16			20%	0.1 mR Jar 5	
			16.7'		16.7'	
801.6			SHALE 17.0'	17.0'	Jar 6	4 mR
801.3	17		Bottom of hole			

PROJECT | HOLE NO. SP-1B

Hole No. SP-2

DRILLING LOG	DIVISION: Environmental Sciences
INSTALLATION	Oak Ridge National Laboratory
SHEET 1 OF 1 SHEETS	
1. PROJECT	SFMP-HRE Soil-Filled pond
2. LOCATION (Coordinates or Station)	N18594.34; E31465.59
3. DRILLING AGENCY	Plant & Equipment Division
4. HOLE NO. (As shown on drawing title and file number)	SP-2
5. NAME OF DRILLER	P. E. Moore
6. DIRECTION OF HOLE	[X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	16.7'
8. DEPTH DRILLED INTO ROCK	0.6'
9. TOTAL DEPTH OF HOLE	17.3'
10. SIZE AND TYPE OF BIT	8" Auger
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	MSL
12. MANUFACTURER'S DESIGNATION OF DRILL	Mobile B-33
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED: 3 Jars; UNDISTURBED:
14. TOTAL NUMBER CORE BOXES	
15. ELEVATION GROUND WATER	
16. DATE HOLE	STARTED: 3/4/85; COMPLETED: 3/4/85
17. ELEVATION TOP OF HOLE	819.21'
18. TOTAL CORE RECOVERY FOR BORING	
19. SIGNATURE OF INSPECTOR	R. G. Stansfield

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
819.2			Asphaltic Pavement 0.4'	A		Water encountered during drilling at depth of approximately 5'.
818.2	1		Crushed Limestone & Clay 1.0'	U		
	2		CLAY (CL) FILL with occasional shale and limestone fragments up to at least 2 1/2" size	GERED		CME sampler installed in auger at depth of 5.0' with end of sampler protruding 0.3' below auger bit. Each sample checked with a G/M meter.
	5		Color is brown to 5.0' depth. Below 5.o', color is brown with zones and inclusions of gray	5.0'	5.0'	At 6' depth, a very locallized portion of the sample read approximately 100 mR as surveyed by Health Physics at the time of sampling.
	7			60%	Jar 1 100 mR	The next highest radioactivity reading was 5 mR at a depth of 9'.
	9					Drill cuttings and excess sample were placed in cans for disposal.
	10			10.3'	10.3'	Boring backfilled with sand and capped with concrete on 3/6/85.
	13			60%	Jar 2 5 mR	
	15			15.3'	15.3'	
	16			80%	Jar 3 2 mR	
802.2	17		17.0'			
801.9			SHALE 17.3'	17.3'	17.3'	
			Bottom of hole			

PROJECT

HOLE NO. SP-2

Hole No. SP-3

DRILLING LOG	DIVISION Environmental Sciences	INSTALLATION Oak Ridge National Laboratory	SHEET 1 OF 1 SHEETS
1. PROJECT SFMP-HRE Soil-Filled Pond		10. SIZE AND TYPE OF BIT 8" Auger	
2. LOCATION (Coordinates or Station) N12579.24, E31486.07		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY Plant & Equipment Division		12. MANUFACTURER'S DESIGNATION OF DRILL Mobile B-33	
4. HOLE NO. (As shown on drawing title and file number) SP-3		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 4 Jars; UNDISTURBED	
5. NAME OF DRILLER P. E. Moore		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
		16. DATE HOLE: STARTED 3/5/85; COMPLETED 3/5/85	
7. THICKNESS OF OVERBURDEN 15.0'		17. ELEVATION TOP OF HOLE 318.01'	
8. DEPTH DRILLED INTO ROCK 0.7'		18. TOTAL CORE RECOVERY FOR BORING %	
9. TOTAL DEPTH OF HOLE 15.7'		19. SIGNATURE OF INSPECTOR R. G. Stansfield	

ELEVATION (ft) a	DEPTH (ft) b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			Visual classification only			
818.0	0		ASPHALTIC PAVEMENT 0.3'	AUGERED		Water encountered during drilling at depth of approximately 4'.
			CRUSHED LIMESTONE AND CLAY 1.0'			
817.0	1		CLAY (CL) FILL with fragments of SHALE and LIMESTONE up to at least 2.5" in size			<0.2 mR CME sampler installed in auger at depth of 5.0' with end of sampler protruding 0.3' below auger bit.
	4				5.0' Jar 1	Sample and drill cutting checked with G/M meter and measurement recorded in Col. "f" in mR. <0.2 mR
	5		Color is brown to 5.0' depth. Below 5.0', color is brown with zones and inclusions of gray			
	8			54%	Jar 2 <0.2 mR	
	10				10.3'	
	13			80%	Jar 3 <0.2 mR	
803.0	15		15.0' SHALE, CALCAREOUS Gray 15.7'	No recovery	15.3' Jar 4	Jar 4 sample obtained from bit of auger 0 mR.
802.3	16		Bottom of hole			Boring backfilled with sand and capped with concrete on 3/6/85.

PROJECT | HOLE NO. SP-3

Hole No. SP-4

DRILLING LOG

Field	Entry
DIVISION	Environmental Sciences
INSTALLATION	Oak Ridge National Laboratory
SHEET	1 OF 1 SHEETS
1. PROJECT	SFMP-HRE Soil-Filled Pond
2. LOCATION (Coordinates or Station)	N18574.05; E31463.83
3. DRILLING AGENCY	Plant & Equipment Division
4. HOLE NO. (As shown on drawing title and file number)	SP-4
5. NAME OF DRILLER	P. E. Moore
6. DIRECTION OF HOLE	[X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	16.3'
8. DEPTH DRILLED INTO ROCK	0.2'
9. TOTAL DEPTH OF HOLE	16.5'
10. SIZE AND TYPE OF BIT	8" Auger
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	MSL
12. MANUFACTURER'S DESIGNATION OF DRILL	Mobile B-33
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED: 4 Jars; UNDISTURBED:
14. TOTAL NUMBER CORE BOXES	
15. ELEVATION GROUND WATER	
16. DATE HOLE	STARTED: 3/6/85; COMPLETED: 3/6/85
17. ELEVATION TOP OF HOLE	818.52'
18. TOTAL CORE RECOVERY FOR BORING	
19. SIGNATURE OF INSPECTOR	R. G. Stansfield

ELEVATION (ft) a	DEPTH (ft) b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			Visual classification only			
818.5			ASPHALTIC PAVEMENT 0.3'	A U G E R E D		Water encountered during drilling at depth of approximately 4'.
817.5	1		CRUSHED LIMESTONE AND CLAY 1.0'			
	2–3		CLAY (CL) FILL with SHALE and LIMESTONE fragments up to at least 2 1/2" size			CME sampler installed in auger at depth of 5.0' with end of sample protruding 0.3' below auger bit.
	4–5		Color is brown to 5.0' depth. Below 5.0', color is brown with zones and inclusions of gray	5.0'	5.0' Jar 1 5.0'	0.3 mR
	6–9			30%	Jar 2 <0.2 mR	Each sample and drill cuttings checked with G/M meter and measurement recorded in Col."f" in mR. Sample in Jar 3 obtained from auger cuttings.
	10			10.3'	10.3'	
	11–14			N O R E C O V E R Y	Jar 3 <0.2 mR	
	15			15.3'	15.3'	
802.2	16		16.3' SHALE, CALCAREOUS	42%	Jar 4	0.3 mR
802.0			16.5' Bottom of hole		16.5'	Boring backfilled with sand and capped with concrete on 3/6/85.

PROJECT | HOLE NO. SP-4

Hole No. MW-1

DRILLING LOG	DIVISION: Environmental Sciences	INSTALLATION: Oak Ridge National Laboratory	SHEET 1 OF 2 SHEETS
1. PROJECT: SFMP-HRE Soil-Filled Pond		10. SIZE AND TYPE OF BIT: 8" Auger	
2. LOCATION (Coordinates or Station): N18634.5. , E31422.37		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL	
3. DRILLING AGENCY: Plant & Equipment Division		12. MANUFACTURER'S DESIGNATION OF DRILL: Mobile B-33	
4. HOLE NO. (As shown on drawing title and file number): MW-1		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 7 Jars; UNDISTURBED	
5. NAME OF DRILLER: P. E. Moore		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
		16. DATE HOLE: STARTED 2/21/85; COMPLETED 2/22/85	
7. THICKNESS OF OVERBURDEN: (Weathered shale)		17. ELEVATION TOP OF HOLE: 823.2'	
8. DEPTH DRILLED INTO ROCK: 28.7'		18. TOTAL CORE RECOVERY FOR BORING %	
9. TOTAL DEPTH OF HOLE: 29.7'		19. SIGNATURE OF INSPECTOR: R. G. Stansfield	

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
823.2	0		ASPHALTIC PAVEMENT 0.3'			Samples and cuttings checked with G/M meter. No readings above background.
			CRUSHED LIMESTONE AND CLAY 1.0'			
822.2	1		SHALE intensely weathered, brown, damp			Jar 1 sample from bit of auger.
	2				Jar 1	
	3				3.0'	
	4				Jar 2	Jar 2 sample from bit of auger.
	5				5.0'	Each sample and drill cuttings checked with a G/M meter; no measurement above background.
	6					
	7					
	8					
	9					Jar samples Nos. 3 through 6 were obtained by driving a split-tube sampler with 140 lb. hammer falling 30 inches for a 100 blow count.
	10		SHALE weathered, gray-brown, damp	100%	10.0' Jar 3 10.4'	
	11					
	12		At approximately 12.0', action of drill indicated approximately 0.2' limestone. Fragments later brought up auger were hard, gray, fine-grained limestone			
	13					
	14					
	15		CALCAREOUS SHALE Rust-stained fractures, gray	100%	15.0' Jar 4 15.4'	Free water first noted on sampler for Jar 4, approximately at 19.0'.
	16					
	17					
	18					
	19					
803.2	20					

PROJECT | HOLE NO. MW-1

Hole No. MW-1

DRILLING LOG	DIVISION Environmental Sciences	INSTALLATION Oak Ridge National Laboratory	SHEET 2 OF 2 SHEETS
1. PROJECT SFMP-HRE Soil-Filled Pond		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number) MW-1		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING %	
9. TOTAL DEPTH OF HOLE		19. SIGNATURE OF INSPECTOR	

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
803.2	20		CALCAREOUS SHALE gray, non-weathered, soft, platey	100%	Jar 5	
					20.4'	
	21					
	22					
	23					
	24					
					25.0'	
	25			100%	Jar 6	
					25.4'	
	26					
	27					
	28					
	29					
793.5	29.7'				Jar 7	100 blows; no advance. LIMESTONE fragment (1" size) recovered, hard, fine-grained.
	30		Bottom of hole			

PROJECT | HOLE NO. MW-1

Hole No. MW-2

DRILLING LOG	DIVISION: Environmental Sciences	INSTALLATION: Oak Ridge National Laboratory	SHEET 1 OF 2 SHEETS
1. PROJECT: SEMP-HRE Soil-Filled Pond Site		10. SIZE AND TYPE OF BIT: 3" Auger	
2. LOCATION (Coordinates or Station): N18581.39; E31,533.62		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL	
3. DRILLING AGENCY: Plant & Equipment Division		12. MANUFACTURER'S DESIGNATION OF DRILL: Mobile B-33	
4. HOLE NO. (As shown on drawing title and file number): MW-2		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 6 Jars; UNDISTURBED	
5. NAME OF DRILLER: P. E. Moore		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
		16. DATE HOLE: STARTED 2/25/85; COMPLETED 2/26/85	
7. THICKNESS OF OVERBURDEN: 5.0'		17. ELEVATION TOP OF HOLE: 813.4'	
8. DEPTH DRILLED INTO ROCK: 19.9'		18. TOTAL CORE RECOVERY FOR BORING %	
9. TOTAL DEPTH OF HOLE: 24.9'		19. SIGNATURE OF INSPECTOR: R. G. Stansfield	

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
813.4	0		CLAY (CL) medium, moist, brown, with shale fragments	AUGERED		
	4				5.0' Jar 1	Sample in Jar 1 taken from bottom of auger.
808.4	5.0'		SHALE extremely weathered from 5.0'-9.5', highly fractured and platey	80%	Jar 2 7.0'	CME sampler installed in auger at depth of 5.0' with end of sampler protruding 0.3' below auger bit. Each sample checked with G/M meter; no measurement above background.
803.9	9.5'		CLAY (CL) medium to soft, moist, greenish gray	10.0'	9.5' Jar 3 10.0'	Removed CME sampler at 13.4' due to termination of advance; continued with auger.
					11.0' Jar 4 11.5'	
801.9	11.5'		SHALE highly weathered, brown, highly fractured	85% 13.4'	12.4' Jar 5	
793.4	20					

PROJECT | HOLE NO. MW-2

Hole No. MW-2

DRILLING LOG	DIVISION Environmental Sciences	INSTALLATION Oak Ridge National Laboratory	SHEET 2 OF 2 SHEETS

1. PROJECT SFMP-HRE Soil-Filled Pond	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) MW-2	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
793.4	20		SHALE platey, fractured, purplish-brown	100%	Jar 6 20.6'	Split-tube sampler 100 blows - 140 lb. hammer.
	21					
	22				NO SAMPLE	
	23					
	24					
788.9			24.5'			
788.5	25		LIMESTONE 24.9' Bottom of hole			

PROJECT | HOLE NO. MW-2

Hole No. MW-3

DRILLING LOG	DIVISION: Environmental Sciences	INSTALLATION: Oak Ridge National Laboratory	SHEET 1 OF 2 SHEETS

1. PROJECT: SFMP-HRE Soil-Filled Pond Site	10. SIZE AND TYPE OF BIT: 8" Auger
2. LOCATION (Coordinates or Station): N18518.64; E31535.36	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
3. DRILLING AGENCY: Plant & Equipment Division	12. MANUFACTURER'S DESIGNATION OF DRILL: Mobile B-33
4. HOLE NO. (As shown on drawing title and file number): MW-3	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 7 Jars; UNDISTURBED
5. NAME OF DRILLER: P. E. Moore	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 2/26/85; COMPLETED 2/27/85
7. THICKNESS OF OVERBURDEN: 8.8'	17. ELEVATION TOP OF HOLE: 808.1'
8. DEPTH DRILLED INTO ROCK: 15.9'	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE: 24.7'	19. SIGNATURE OF INSPECTOR: R. G. Stansfield

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
808.1	0		CLAY (CL) medium, moist, brown 0.5'		Jar 1 0.5'	Pushed 5.0' CME sampler to 5.0'
	1–5		SHALE AND CLAY approximately equal mix of shale fragments and clay, fragments from sand-size to 2.0", moist, brown to yellowish-brown, at 5.0' changes to: CLAY (CL) some shale fragments, moist, greenish-gray	78% 5.0'	Jar 2 2.0'; 4.0' Jar 3 5.0'	Each sample and drill cuttings checked with G/M meter; no measurement above background. Water encountered in cuttings at approximately 8.0' depth. CME sampler removed at 12.2' as could not advance further in shale. Limestone classified by drilling action at 17.0'.
	6–8			94%	6.0' Jar 4 7.0'	
799.3	9		8.8' SHALE weathered 9.3'	10.0'	9.0' Jar 5 10.0'	
	10–12		SHALE greenish-gray platey calcareous	100%	11.0' Jar 6 12.2'	
	13–16					
791.1	17		17.0' LIMESTONE 17.5' SHALE calcareous			
	18–19					
788.1	20					

PROJECT | HOLE NO. MW-3

Hole No. MW-3

DRILLING LOG	DIVISION Environmental Sciences	INSTALLATION Oak Ridge National Laboratory	SHEET 2 OF 2 SHEETS

1. PROJECT SFMP-HRE Soil-Filled Pond	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) MW-3	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
788.1	20		SHALE calcareous			
	21					
	22		Approximately 0.2' of LIMESTONE at 22.3'			
	23					
	24		24.7'		24.7' Jar 7	Sample from drill bit
783.4	25		Bottom of hole			

PROJECT HOLE NO. MW-3

Hole No. MW-4A

DRILLING LOG	DIVISION: Environmental Sciences	INSTALLATION: Oak Ridge National Laboratory	SHEET 1 OF 1 SHEETS
1. PROJECT: SFMP-HRE Soil-Filled Pond		10. SIZE AND TYPE OF BIT: 8" Auger	
2. LOCATION (Coordinates or Station): N18515.45; E31444.65		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL	
3. DRILLING AGENCY: Plant & Equipment Division		12. MANUFACTURER'S DESIGNATION OF DRILL: Mobile B-33	
4. HOLE NO. (As shown on drawing title and file number): MW-4A		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 1 Jar	UNDISTURBED
5. NAME OF DRILLER: P. E. Moore		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE: X VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN: 1.0'		16. DATE HOLE: STARTED 2/23/85	COMPLETED 2/28/85
8. DEPTH DRILLED INTO ROCK: 23.7'		17. ELEVATION TOP OF HOLE: 813.1'	
9. TOTAL DEPTH OF HOLE: 24.7'		18. TOTAL CORE RECOVERY FOR BORING %	
		19. SIGNATURE OF INSPECTOR: R. G. Stansfield	

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
813.1	0		(See Log of boring MW-4)			MW-4A located approximately 2.0' NE of MW-4.
803.1	10		10.0' SHALE weathered, brown, platy	10.0'	Jar 1 11.0'	<0.2 mR/hr
	11			100%		Boring MW-4A started upslope from MW-4 so that any radioactive water from MW-4A would drain into MW-4.
	12		12.4'	12.4'		CME sampler removed at 12.4' as unable to advance further in shale.
	13		SHALE slightly weathered to non-weathered		NO SAMPLE	Each sample and cuttings checked with G/M meter. Only radioactivity measured above background was cuttings and sample at 10'. Cuttings were placed in cans for disposal.
788.4	25		24.7' Bottom of hole			Note: Monitoring Well No. MW-4 was constructed in this boring.

PROJECT | HOLE NO. MW-4A

Hole No. MW-4

DRILLING LOG

DIVISION	Environmental Sciences
INSTALLATION	Oak Ridge National Laboratory
SHEET 1 OF 1 SHEETS	
1. PROJECT	SFMP-HRE Soil-Filled Pond Site
2. LOCATION (Coordinates or Station)	(Approx. 2' SW of MW-4A)
3. DRILLING AGENCY	Plant & Equipment Division
4. HOLE NO. (As shown on drawing title and file number)	MW-4
5. NAME OF DRILLER	P. E. Moore
6. DIRECTION OF HOLE	☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	1.0'
8. DEPTH DRILLED INTO ROCK	9.0'
9. TOTAL DEPTH OF HOLE	10.0'
10. SIZE AND TYPE OF BIT	8" Auger
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	MSL
12. MANUFACTURER'S DESIGNATION OF DRILL	Mobile B-33
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED: 2 jars; UNDISTURBED:
14. TOTAL NUMBER CORE BOXES	
15. ELEVATION GROUND WATER	9.0 below ground
16. DATE HOLE	STARTED: 2/27/85; COMPLETED: 2/27/85
17. ELEVATION TOP OF HOLE	813' approximately
18. TOTAL CORE RECOVERY FOR BORING	%
19. SIGNATURE OF INSPECTOR	R. G. Stansfield

ELEVATION (ft)	DEPTH (ft)	LEGEND	CLASSIFICATION OF MATERIALS (Description) Visual classification only	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
813.0	0		ASPHALTIC PAVEMENT 0.4'			Installed CME sample at 2.0' and pushed to 3.1' to refusal. Then augered to 5.0' and reinstalled CME sampler. Drilled with CME sampler in place to 10.0'.
			CRUSHED STONE AND CLAY 1.0'			
812.0	1		SHALE calcareous, weathered			
	2			100%	2.0' Jar 1 3.1'	
	3		Approximately 0.2' LIMESTONE LENSE at 3.1'			Each sample and cuttings checked with G/M meter; measurement recorded in Col. "f" in mR.
	4					
	5			5.0'		
	6					
	7			80%		
	8				8.5'	
	9				Jar 2	Radioactivity 1000 CPS or ~0.3 mR
803.0	10		Bottom of hole 10.0'		9.5'	Boring terminated at 10.0' because of the potential of radio-active groundwater being brought to the surface by the auger.
	11					
	12					Drill cutting, placed in cans for disposal.
	13					Boring was filled with sand and clay and capped with concrete on 3/6/85.
	14–20					

PROJECT | HOLE NO. MW-4

APPENDIX C

GROUNDWATER MONITORING WELL REPORTS: MW-1 through MW-4

GROUND WATER OBSERVATION WELL REPORT

PROJECT SFMP Ponds

LOCATION HRE Pond: N18,634.87; E31422-87

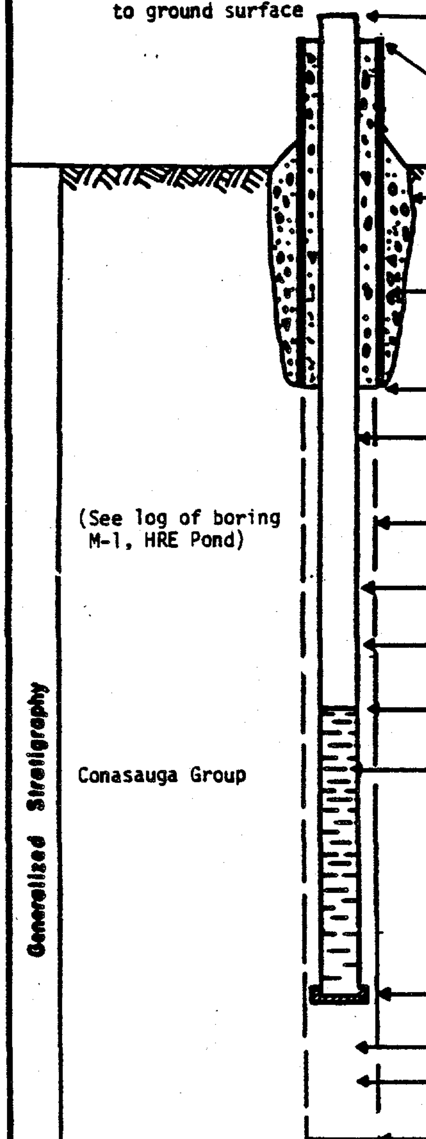
Date Completed 2/25/85 **Original Depth** 26.2' below ground surface

Elevation top of well riser pipe = 827.03'

Well No. MW-1

Aquifer Uppermost (Water table)

Note: All depths and heights are referenced to ground surface



Height of riser pipe above ground surface	3.8'
Height of top of surface casing pipe above ground surface	2.0'
Depth of surface seal below ground surface	3.0'
Type of surface seal: Concrete	
I.D. of surface casing	4.0"
Type of surface casing: Steel	
Depth of surface casing below ground	3.0'
I.D. of riser pipe:	3.0"
Type of riser pipe: Fiberglass	
Diameter of borehole	8.0"
Depth of borehole	29.7'
Type of backfill: Concrete	
depth top of seal	6.0'
Type of seal: Bentonite	
depth bottom of seal	8.0'
Type of sand pack: Medium-grained silica sand	
Depth of top of sand pack	8.0'
depth top of screened section	16.2'
Type of screened section: Fiberglass	
Discribe openings Slotted, 2 sides, 0.01" at 1" intervals	
I.D. of screened section	3.0"
depth bottom of screened section	26.2'
depth bottom of sand column	28.0'
Type of backfill below observation pipe. In-place drill cuttings	
depth of hole	29.7'

GROUND WATER OBSERVATION WELL REPORT

PROJECT SFMP Ponds

LOCATION HRF Pond: N18581.39; E31533.62

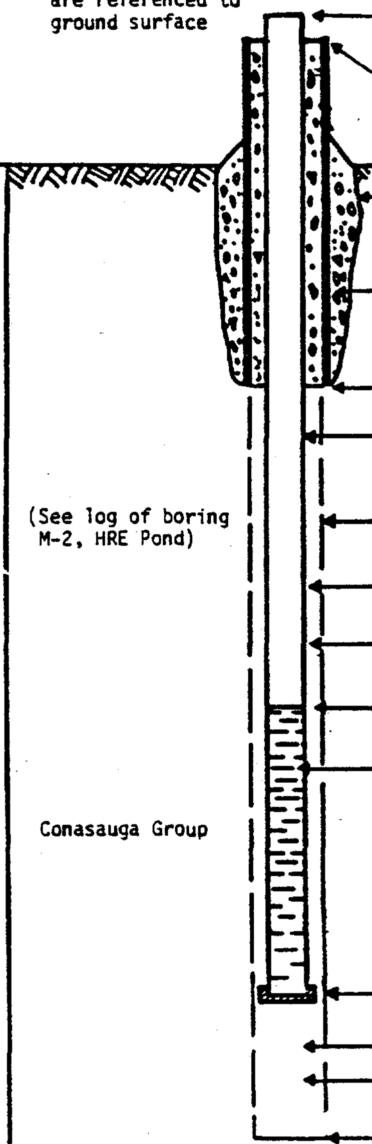
Date Completed 2/26/85 **Original Depth** 22.7' below ground surface

Elevation top of well riser pipe = 815.71'

Well No. MW-2

Aquifer Uppermost (Water table)

Note: All depths and heights are referenced to ground surface



Generalized Stratigraphy

(See log of boring M-2, HRE Pond)

Conasauga Group

Height of riser pipe above ground surface	2.3'
Height of top of surface casing pipe above ground surface	2.0'
Depth of surface seal below ground surface	3.0'
Type of surface seal: Concrete	
I.D. of surface casing	4.0"
Type of surface casing: Steel	
Depth of surface casing below ground	3.0'
I.D. of riser pipe:	3.0"
Type of riser pipe: Fiberglass	
Diameter of borehole	8.0"
Depth of borehole	24.9'
Type of backfill: Concrete	
depth top of seal	6.0'
Type of seal: Bentonite	
depth bottom of seal	8.0'
Type of sand pack Medium-grained silica sand	
Depth of top of sand pack	8.0'
depth top of screened section	12.7'
Type of screened section: Fiberglass	
Discribe openings Slotted, 2 sides, 0.01" slots at 1" intervals	
I.D. of screened section	3.0"
depth bottom of screened section	22.7'
depth bottom of sand column	23.0'
Type of backfill below observation pipe In-place, drill cuttings	
depth of hole	24.9'

GROUND WATER OBSERVATION WELL REPORT

PROJECT SFMP Ponds

LOCATION HRE Pond: N18518.64; E31525.86

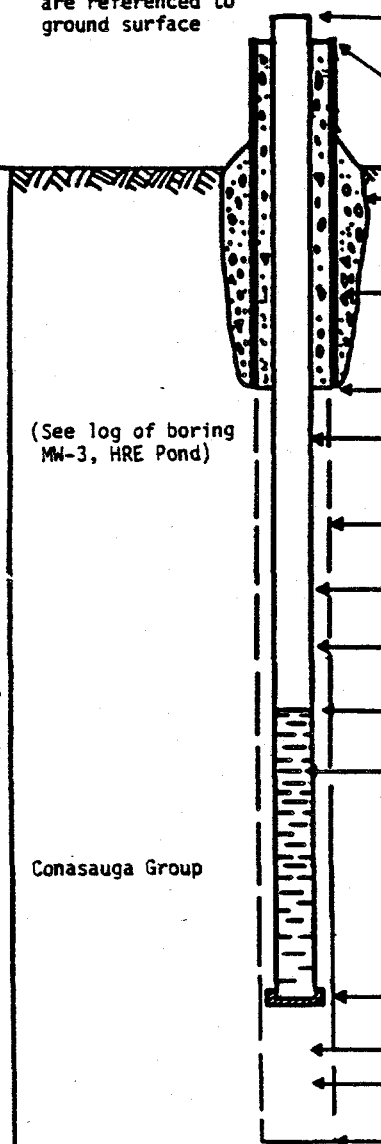
Date Completed 2/27/85 **Original Depth** 22.3' below ground surface

Elevation top of well riser pipe = 810.31'

Well No. MW-3

Aquifer Uppermost (Water table)

Note: All depths and heights are referenced to ground surface



(See log of boring MW-3, HRE Pond)

Conasauga Group

Generalized Stratigraphy

Height of riser pipe above ground surface	2.7'
Height of top of surface casing. pipe above ground surface	2.5'
Depth of surface seal below ground surface	2.34'
Type of surface seal: Concrete	
I.D. of surface casing.	4.0"
Type of surface casing: Steel	
Depth of surface casing below ground	2.5'
I.D. of riser pipe.	3.0"
Type of riser pipe: Fiberglass	
Diameter of borehole	8.0"
Depth of borehole	24.7'
Type of backfill: Concrete	
depth top of seal.	6.0'
Type of seal: Bentonite	
depth bottom of seal	8.0'
Type of sand pack. Medium-grained silica sand	
Depth of top of sand pack.	8.0'
depth top of screened section.	12.3'
Type of screened section: Fiberglass	
Discribe openings Slotted 2 sides; 0.02" slots at 1" intervals	
I.D. of screened section.	3.0"
depth bottom of screened section	22.3'
depth bottom of sand column.	23.0'
Type of backfill below observation pipe. In-place, drill cuttings	
depth of hole.	24.7'

GROUND WATER OBSERVATION WELL REPORT

PROJECT SFMP Ponds

LOCATION HRE Pond: N18515.45; E31444.65

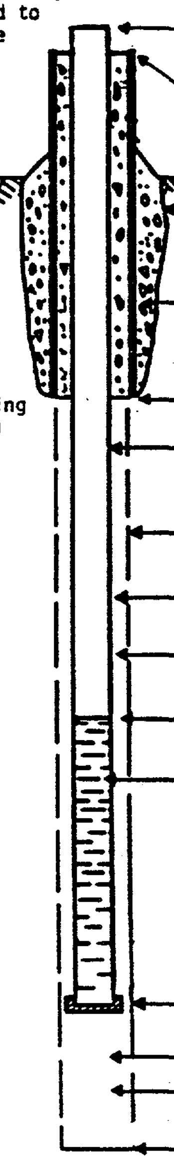
Date Completed 3/4/85 **Original Depth** 18.7' below ground surface

Well No. MW-4

Aquifer Uppermost (Water table)

Elevation top of well riser pipe = 816.10'

Note: All depths and heights are referenced to ground surface



(See log of boring MW-4, HRE Pond)

Conasauga Group

Generalized Stratigraphy

Height of riser pipe above ground surface	3.0'
Height of top of surface casing. pipe above ground surface	2.8'
Depth of surface seal below ground surface	2.3'
Type of surface seal: Concrete	
I.D. of surface casing.	4.0"
Type of surface casing: Steel	
Depth of surface casing below ground	2.2'
I.D. of riser pipe:	3.0"
Type of riser pipe: Fiberglass	
Diameter of borehole	8.0"
Depth of borehole	24.7'
Type of backfill: Concrete	
depth top of seal.	6.0'
Type of seal: Bentonite	
depth bottom of seal.	8.0'
Type of sand pack. Medium-grained silica sand	
Depth of top of sand pack.	8.0'
depth top of screened section.	8.7'
Type of screened section: Fiberglass	
Discribe openings Slotted 2 sides; 0.01" slots at 1" intervals	
I.D. of screened section.	3.0"
depth bottom of screened section	18.7'
depth bottom of sand column.	18.0'
Type of backfill below observation pipe. In-place drill cuttings	
depth of hole.	24.7'

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